PHILOSOPHICAL

TRANSACTIONS,

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCXX.

PART I.

LONDON,

PRINTED BY W. BULMER AND W. NICOL, CLEVELAND ROW, ST. JAMES'S;
AND SOLD BY G. AND W. NICOL, PALL-MALL, BOOKSELLERS TO HIS MAJESTY,
AND PRINTERS TO THE ROYAL SOCIETY

MDCCCXX.

PHILOSOPHICAL

TRANSACTIONS,

OF THE

ROYAL SOCIETY

OF

LONDON,

FOR THE YEAR MDCCCXX.

PART I.

LONDON:

PRINTED BY W. NICHOLS, AND SON, CHANDOS ROW, ST. JAMES'S;
AND SOLD AT SOMERSET HOUSE, PALL-MALL, BOOKSELLERS TO HIS MAJESTY,
AND PRINTERS TO THE ROYAL SOCIETY.
MDCCCXX.

ADVERTISEMENT.

THE Committee appointed by the *Royal Society* to direct the publication of the *Philosophical Transactions*, take this opportunity to acquaint the Public, that it fully appears, as well from the council-books and journals of the Society, as from repeated declarations which have been made in several former *Transactions*, that the printing of them was always, from time to time, the single act of the respective Secretaries, till the Forty-seventh Volume: the Society, as a Body, never interesting themselves any further in their publication, than by occasionally recommending the revival of them to some of their Secretaries, when, from the particular circumstances of their affairs, the *Transactions* had happened for any length of time to be intermitted. And this seems principally to have been done with a view to satisfy the Public, that their usual meetings were then continued, for the improvement of knowledge, and benefit of mankind, the great ends of their first institution by the Royal Charters, and which they have ever since steadily pursued.

But the Society being of late years greatly enlarged, and their communications more numerous, it was thought advisable that a Committee of their members should be appointed, to reconsider the papers read before them, and select out of them such as they should judge most proper for publication in the future *Transactions*; which was accordingly done upon the 26th of March, 1752. And the grounds of their choice are, and will continue to

27691

be, the importance and singularity of the subjects, or the advantageous manner of treating them; without pretending to answer for the certainty of the facts, or propriety of the reasonings, contained in the several papers so published, which must still rest on the credit or judgment of their respective authors.

It is likewise necessary on this occasion to remark, that it is an established rule of the Society, to which they will always adhere, never to give their opinion, as a Body, upon any subject, either of Nature or Art, that comes before them. And therefore the thanks, which are frequently proposed from the Chair, to be given to the authors of such papers as are read at their accustomed meetings, or to the persons through whose hands they received them, are to be considered in no other light than as a matter of civility, in return for the respect shewn to the Society by those communications. The like also is to be said with regard to the several projects, inventions, and curiosities of various kinds, which are often exhibited to the Society; the authors whereof, or those who exhibit them, frequently take the liberty to report, and even to certify in the public news-papers, that they have met with the highest applause and approbation. And therefore it is hoped, that no regard will hereafter be paid to such reports and public notices; which in some instances have been too lightly credited, to the dishonour of the Society.

CONTENTS.

I. *The Croonian Lecture. A farther investigation of the component parts of the Blood. By Sir* EVERARD HOME, *Bart. V. P. R. S.* p. 1

II. *The Bakerian Lecture. On the composition and analysis of the inflammable gaseous compounds resulting from the destructive distillation of coal and oil, with some remarks on their relative heating and illuminating powers. By* WILLIAM THOMAS BRANDE, *Esq. Sec. R. S. Prof. Chem. R. I.* p. 11

III. *On the Elasticity of the Lungs. By* JAMES CARSON, *M. D. Communicated by* THOMAS YOUNG, *M. D. For. Sec. R. S.* p. 29

IV. *On the action of crystallized bodies on homogeneous light, and on the causes of the deviation from* NEWTON'S *scale in the tints which many of them develope on exposure to a polarised ray. By* J. F. W. HERSCHEL, *Esq. F. R. S. Lond. and Edin.* p. 45

V. *A case of the human fœtus found in the ovarium, of the size it usually acquires at the end of the fourth month. By* A. B. GRANVILLE, *M. D. F. R. S. In a letter addressed to Sir* EVERARD HOME, *Bart., V. P. R. S.* p. 101

VI. *On some combinations of Platinum. By* EDMUND DAVY, *Esq. Professor of Chemistry, and Secretary to the Cork Institution. Communicated by* F. BABINGTON, *M. D. F. R. S.* p. 108

VII. *On the methods of cutting rock crystal for micrometers.* By WILLIAM HYDE WOLLASTON, *M. D. F. R. S.* p. 126

APPENDIX.

Meteorological Journal Kept at the Apartments of the Royal Society, by Order of the President and Council.

PHILOSOPHICAL TRANSACTIONS.

I. *The Croonian Lecture. A farther investigation of the component parts of the Blood.* By *Sir* EVERARD HOME, *Bart. V. P. R. S.*

Read November 4, 1819.

As the capacity of one individual is rarely able to bring to perfection different branches of science, it is no wonder that, in the investigation of so complex a subject as the component parts of the blood, HEWSON failed, HUNTER fell short in the attempt, and Dr. YOUNG, after the interesting discovery of the colouring matter being readily separated from the red globules, made no farther advance. This view of the subject, led me, at the time I ventured upon this enquiry, to engage as my associates, Mr. BAUER, whose microscopical observations have been too long put to the proof, to admit of their being disputed; and Professor BRANDE, whose chemical researches, and the judgment with which they have been pursued, are fully established.

In two former Lectures, assisted by these skilful coadjutors, I have been enabled to prove, that the human blood in the

act of coagulation, evolves aeriform matter, so as to pervade the coagulum in every direction; and that such currents, passing through the serum, form permanent tubes, which are immediately afterwards filled with red blood, when the circumstances in which the coagulum is placed, admit of their being so.

In the present Lecture, I trust that I am enabled to make out the greater number, if not the whole, of the component parts of the blood.

My former experiments were made upon coagula recently formed from the blood, whether out of the body, or in the interstices of parts possessed of life. Upon the present occasion, I have taken an opposite course, and have examined the coagula formed in aneurismal tumors. It is to be understood, that in this disease of the arteries, the coats at the part diseased, yield to the impulse of the heart, and admit of being permanently dilated, so as to form a pouch, in which the blood that remains at rest, coagulates. This dilatation is gradual; and as the pouch enlarges, the coagulum is found to be made up of a succession of layers, affording an opportunity of observing the changes coagulated blood undergoes under such circumstances at different periods of time.

In the examination of the section of an aneurismal tumor in the microscope, Mr. BAUER found that the layer of the coagulum, in contact with the blood in circulation, was red in its colour, loose in its texture, and principally consisted of red globules from which the colour had been discharged, and remained diffused through the mass. Besides these globules, he saw others of a smaller size, which he had never met with in fluid blood, however frequently he had examined

it; there was also a small quantity of a transparent elastic mucus insoluble in water. The newly discovered globules were $\frac{1}{1000}$ part of an inch in diameter, and their number in proportion of one to four of the large ones. The other layers, in proportion to the length of time coagulation had taken place, were become paler in colour, denser in texture, and what is most particularly deserving of notice in the present investigation, the proportion of the number of the small globules to the large ones gradually increased, and in the layer longest coagulated, they were in the proportion of four to one. In this layer there was also the largest proportion of the transparent elastic mucus.

The coat of the artery forming the pouch, appeared to be made up of zig-zag, or serpentine fibres, connected by the elastic mucus, in which many of the small globules were detected.

The condensed cellular membrane on the outside of the pouch, consisted of thin membranes or films, easily separated, and between them were found many small globules.

In the section of a large aneurismal tumor a deposit of crystals was met with. This uncommon appearance is represented in the annexed drawings. These salts, in the absence of Professor BRANDE, were analyzed by Mr. FARADAY, Assistant in the Laboratory of the Royal Institution: they are sulphate of lime with muriate and phosphate of soda; salts usually met with in the blood, but probably never before seen in the form of crystals.

The discovery of small globules in aneurismal coagula, and the increase of their number in proportion to the dura-

tion of the coagulum, throws great light upon the materials of which the blood is composed.

Till this discovery was made, we knew of no globules in the blood but the red globules, either enclosed in their colouring matter, or deprived of it: indeed these smaller ones being held in solution in the serum, are only brought to view by the act of coagulation, and under the same circumstances we find the salts crystallize.

To ascertain whether these small globules constitute the substance thrown out in inflammation, Mr. BAUER examined a small portion of a mass of coagulable lymph taken from the vagina of an ass, where it had been deposited by a violent attack of inflammation; and another portion from the internal surface of an inflamed vein.* He found both substances made up of the small globules just discovered, mixed with a few red globules, deprived of their colouring matter. The globules which in a former Lecture were stated to have been produced in the serum, are now found to be similar to these, and had been held in solution in the serum when put into the tube.

The globules found by BASILIUS in the serum, after filtration through paper, must have been of the same kind.

In the prosecution of this enquiry, I procured the coagulum of some highly inflamed blood, as it is termed. The buff was very thick and firm, the lower portion loose in its texture. Mr. BAUER found the buff to consist almost wholly of the small globules, which I shall now call those of lymph,

* Both of these preparations are described in HUNTER's Work upon the Blood, Inflammation, and Gun-shot Wounds.

and the lower portion principally of red globules; so that the buffy appearance occurs when the lymph is so unusually slow in coagulating, that the red globules, which are so much larger and heavier, sink before that process has taken place.

In the absence of Professor BRANDE, Mr. FARADAY analyzed a portion of the buff, and of the part made up of red globules: having previously washed away the colouring matter, their chemical properties were in all respects the same.

That I might compare the structure of tumors, with that of the layers in aneurismal coagula, I got Mr. BAUER to examine in the microscope the structure of a tumor in the prostate gland, made up of rounded nodules; the last formed of these was produced by the bursting of a small artery in the substance of the gland, so short a time before death, that the rupture of the vessel was distinctly seen when the parts were examined. He found the texture of the tumor soft and spongy; it was made up almost wholly of red globules free from colour, very few of those of lymph, and some of the transparent elastic jelly; the bands by which the nodules were separated, were composed of three-fourths of lymph, one-fourth of red globules from which the colour had been discharged, and a considerable proportion of the transparent jelly.

A tumor in the breast of long standing, of which the first formed part was hard and colourless, the last less compact and full of vessels or tubes, is shown in the annexed drawings. When its structure was examined in the microscope, the hard part was made up almost wholly of lymph globules, and elastic jelly; the last made one-fourth of the whole. The

soft part consisted only of about one-fourth of lymph globules, the rest being red globules which had lost their colour.

The structure of such tumors is nearly allied to that of the layers in an aneurism. That these layers never become vascular, arises from the aeriform matter, evolved at the time that the blood coagulates, readily escaping into the circulating blood with which it is in contact.

To ascertain whether the proportion of aeriform matter in the blood is liable to vary, as well as to determine its nature, a very buffy coagulum was placed in the receiver of an air pump, with a syphon passing from the vessel containing it into a bottle filled with barytes water. The pump was worked, and the gas only came over in single bubbles, which occasioned a precipitation of carbonate of barytes. From a less buffy coagulum the gas came over in several bubbles at a time. When there was no buff, the gas was abundant, and the precipitation copious. To ascertain whether this gas is produced in the process of digestion, a pauper from one of our work-houses, an hour after eating a hearty dinner and drinking a pint of porter, was bled at the arm to six ounces. The coagulum was tested in the same manner as the others in the air pump, and at the same distance of time from that at which the blood was drawn, the gas passed through the syphon in a torrent, and there was a proportionate precipitation.

Carbonic acid gas, Professor BRANDE finds to be commonly met with in the urine; but in greater quantity immediately after a full meal.

The source from whence the carbonic acid gas is supplied, having been thus determined, an attempt was made to trace

the lymphatic and red globules to their origin. The pyloric portion of the stomach, and the duodenum, are filled with a glary mucus. Mr. BAUER found in this mucus a great number of lymph globules and a smaller number of red globules without colour, so that such globules appear to be produced in the earliest stage of digestion.

In the human species the produce of the process of digestion becomes white, and therefore is readily distinguished from any other fluids; in general it is first met with in this state in the beginning of the jejunum, but sometimes in the whole course of the duodenum; the readiness with which this substance is absorbed, and the velocity with which it is carried along the lacteal vessels, make it difficult to procure enough for examination till it reaches the glands in the mesentery, through which it must pass before it arrives at the thoracic duct.

An opportunity occurred of making this examination upon the contents of the mesenteric glands, of a man who died in a fit an hour after having eaten his dinner. Mr. BAUER having extricated some of the glands of the mesentery from the surrounding fat and cellular membrane, divided them transversely, when a quantity of milk-white fluid issued out. On examination, the white colour was found to depend upon an infinity of white globules floating in a clear, perfectly colourless fluid, in the same manner as the red globules do in the serum. About eight-tenths of these globules varied in size from the smallest speck to the size of the lymph globules, about one-tenth were of the size of red globules deprived of the colouring matter, and about one-twentieth were of the size of the red globules enclosed in their colouring matter. When

this fluid was left a few minutes on the glass, not only many new globules were formed, but the original small ones visibly increased on the field of the microscope, not by several globules uniting, but by accession of substance; and he watched several that enlarged to the full size of blood globules enclosed in their colouring matter: in that state they appeared more opaque; and when the glass was laid upon black paper, they appeared as distinctly to be milk-white, as the globules of the blood when the glass is laid upon white paper appeared to be bright red. When the fluid is diluted with water, no additional globules are produced, and the large ones are reduced in size, in the same manner as the red globules are, when their colouring matter is dissolved, and is leaving them. When there is a sufficient quantity of the fluid left to evaporate, ramifications are formed in every respect as distinct as those shown in a former Lecture, in the magnified drawing of a drop of human blood in the state of coagulation.

From the observations Mr. BAUER has had the opportunity of making upon the contents of the lacteal glands, he is satisfied that the full sized globules acquire that form in these glands, and that afterwards, so far as respects their external appearance, no change is necessary for their conversion into red globules, but their becoming red.

As the exposure of the blood to the air in its passage through the lungs, restores the brilliancy of colour that is lost in the circulation through the body, we can have no doubt that it is in the vessels of the lungs the blood receives its original hue.

EXPLANATION OF THE PLATES.

PLATE I.

Contains three figures; the first exhibits a transverse section of an aneurismal coagulum of the natural size; the other two represent the salts of the blood in a crystallized state, magnified five diameters.

Fig. 1. This section represents that part of the coagulum which lay in the bottom of the sac. It shows the different shades of colour of the layers according to their length of standing, and the crystallized salts in different parts of the coagulum.

Figs. 2 and 3. Different views of these crystals.

PLATE II.

Represents sections of a tumor taken from a patient in St. George's Hospital: there are seven figures.*

Fig. 1. The surface of the section of the natural size; one part is colourless; another appears to be very vascular.

* The following is an account of the case. The tumor was perceived when of the size of a pea: in six months it increased to that of an orange: in fourteen days more it doubled that size. Arsenic, 48 grs. to ℥i. of water, was applied once in twenty-four hours for two days. The pain was too great to allow it to be renewed In ten days the application was taken off, and the tumor was black and shrunk, but not dead to any depth. Equal parts of white arsenic and sulphur were applied once in twenty-four hours for two days: the pain was excessive. In fourteen days, one half of the tumor came away. The remaining surface resembled a coagulum of blood, soft and dark coloured. This came away next day, eight months and a half from the first appearance of the tumor. This last is the tumor of which a section is represented. The drawing was made twenty-four hours after it was removed, in which time it had undergone no change.

Figs. 2 and 3. Portions of the vascular part, magnified five diameters.

Fig. 4. A small portion of the colourless part, magnified 200 diameters, to show the lymph globules, of which it is made up.

Fig. 5. A similar portion of the vascular part, magnified in the same degree.

Fig. 6. A row of lymph globules, magnified 400 diameters.

Fig. 7. A row of blood globules deprived of their red colour; magnified 400 diameters.

Fig. 1.

Fig. 2.

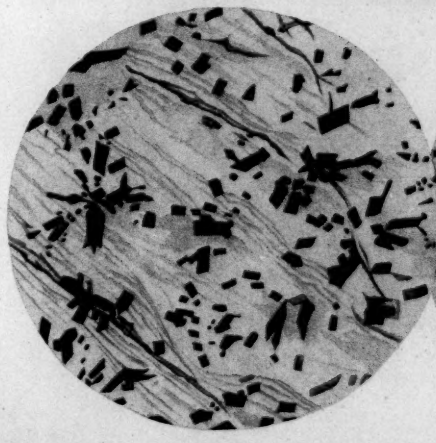


Fig. 3.

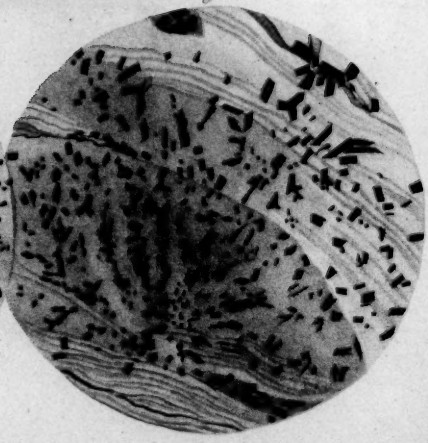


Fig. 1.

Natural size.

Fig. 2.

Fig. 3.

Fig. 4.

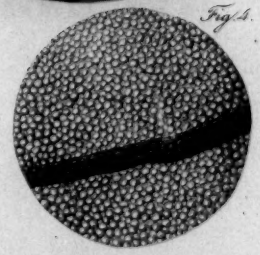


Fig. 5.

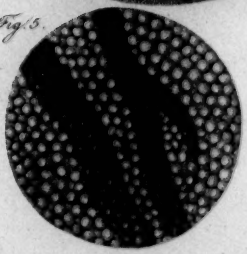


Fig. 6.

Fig. 7.

Franz Bauer del.

P. Bauer sc.

II. *The Bakerian Lecture. On the composition and analysis of the inflammable gaseous compounds resulting from the destructive distillation of coal and oil, with some remarks on their relative heating and illuminating powers.* By WILLIAM THOMAS BRANDE, *Esq. Sec. R. S. Prof. Chem. R. I.*

Read November 18, 1819.

THE experiments detailed in the following pages, were originally undertaken with a view of ascertaining the relative fitness of the gases obtained by the decomposition of coal and oil for the purposes of illumination, and of elucidating some apparent anomalies in their economical applications. Merely as such, however, I should not have deemed them of sufficient novelty or importance to form the subject of the Bakerian Lecture; but during the progress of the inquiry, some new views relative to the constitution of these gaseous mixtures, suggested themselves, and some properties of terrestrial radiant matter became apparent, which I trust will be thought worthy the attention of this Society.

SECTION I.

On the inflammable gases afforded by the destructive distillation of pit coal and of oil.

THE gases used in the following experiments, except where it is otherwise expressly stated, were those employed for the

common purposes of illumination; the coal gas being that supplied from the Company's works in Westminster, and the oil gas furnished by the decomposition of common whale oil, in an apparatus erected for that purpose by Messrs. TAYLORS and MARTINEAU, at Apothecaries' Hall.* These gases have been submitted to analysis by different chemists of eminence; and we are more especially indebted to Dr. HENRY for a series of valuable researches respecting their production and composition.† It is therefore with considerable diffidence that I venture to propose views relating to them in many respects different from those of my predecessors in this important branch of chemical inquiry.

It is generally admitted, that there are two definite compounds of carbon and hydrogen; the one, usually termed *olefiant gas*, consisting of *one* proportional of carbon and *one* of hydrogen; and the other called *light hydrocarburet*, composed of *one* proportional of carbon and *two* of hydrogen: the former of these gases appears to have been discovered in 1796, by the associated Dutch chemists, Messrs. BONDT, DIEMAN, VAN TROOSTWICK, and LAWERENBOURG,‡ and the other first examined by Mr. DALTON.§ Assuming hydrogen as 1, the specific gravity of olefiant gas is 18,4; and it contains 1 proportional of carbon = 5,7 + 1 proportional of hydrogen = 1. Light hydrocarburet has generally been

* A description and plate of this apparatus is given in the Quarterly Journal of Sciences, &c. Vol VIII. p. 120.

† NICHOLSON's Journal, Vol. XI. p. 65. Philos. Trans. 1808. Manchester Memoirs, Vol. III. New Series.

‡ Journal de Physique, XIV. § New System of Chemical Philosophy.

considered as consisting of 1 proportional of carbon = 5,7 + 2 proportionals of hydrogen = 2, and its specific gravity has been stated as 7,7 compared with hydrogen; or as 57865, assuming atmospheric air as 1.

My first object in the examination of coal gas was to ascertain its specific gravity; and I was surprised to find the first that I examined so low as ,4480. There was some variation in different specimens; and the specific gravity of that prepared in the laboratory of the Royal Institution, and purified in the usual way by condensation in cold vessels, and passing through lime water, was as high as ,4940, which is the heaviest that I have yet met with.

Having been led to consider coal gas as consisting essentially of the two varieties of carburetted hydrogen, I imagined that the specific gravity of the light hydrocarburet must have been estimated too high; I therefore prepared light hydrocarburet from acetate of potash, and having separated its carbonic acid by lime, found its specific gravity ,687; the specific gravity of the gas from stagnant water, according to Mr. DALTON,* is ,600, and that from moistened charcoal when purified is ,480.† It became evident, therefore, that coal gas could not consist principally of the two hydrocarburets; nor could the presence of carbonic oxide be suspected, its specific gravity being ,9834. Hence it occurred to me, that the only mode of explaining these apparent anomalies, was to consider coal gas as a mixture of olefiant and hydrogen gases; and the following experiments were undertaken with a view to determine this point.

* New System of Chemical Philosophy. † HENRY's Elements, p. 320.

1. One hundred volumes of coal gas were detonated by the electric spark over mercury, with 200 of oxygen; the carbonic acid was absorbed by liquid potassa, and 36 volumes of pure oxygen remained in the tube. Whence it appears that 100 volumes of the coal gas under examination required for its perfect combustion 164 parts of oxygen; consequently, as 100 parts of olefiant gas require 300 of oxygen, and 100 of hydrogen 50, for their respective combustion, it might be concluded from the above experiments, supposing no foreign gases present, that the 100 of coal gas consisted of about 55 parts of hydrogen and 48 of olefiant gas; a mixture, of which 100 cubical inches would weigh nearly 15 grains, and which closely corresponds with the specific gravity of the coal gas.

2. One hundred measures of coal gas were introduced into a small bent glass tube containing a little sulphur, and inverted in mercury; a red heat was applied until the inclosed gas underwent no further dilatation; and on examining its volume when cold, it was found to occupy 140 measures. If we consider the increase of bulk as resulting from the decomposition of olefiant gas, this experiment gives the composition of coal gas 60 hydrogen and 40 olefiant by volume.

3. One hundred measures of coal gas were introduced into a mercurial gasometer, connected with a second gasometer by means of a platinum tube, in the manner described by Messrs. ALLEN and PEPYS, in their Essay on the Combustion of Carbon.* Some small quartz crystals previously heated red hot were introduced into the platinum tube, which was heated bright red; the gas was then passed through it from

* Phil. Trans. 1807.

one gasometer to the other for about a quarter of an hour. The apparatus having cooled, the gas was found to have sustained an increase of volume = 40 parts; it burned with the pale flame of hydrogen; and when detonated over mercury required scarcely more than half its volume of oxygen, and afforded a very minute portion of carbonic acid. The interior of the platinum tube was lined with charcoal, the crystals were covered with it, and some had assumed a beautiful brown tint.

4. The conclusions drawn from the last experiment are founded upon the supposition, that olefiant gas is decomposed by the simple operation of a high temperature, and that one volume is resolved into two volumes of hydrogen, losing at the same time its carbon. The importance of this fact, as connected with these researches, induced me to repeat with every requisite precaution, the beautiful experiment of M. BERTHOLLET, which consists in decomposing this gas by passing it repeatedly through a red hot earthen tube; instead of which, however, I employed a tube of platinum, arranged as in the last experiment, increasing the heated surface by the introduction of quartz crystals. One hundred measures of olefiant gas,* obtained by distilling alcohol with sulphuric acid, were passed and repassed through the tube heated to high redness, until they ceased to dilate: when the apparatus was cool, the volume of gas was almost exactly doubled; there was a copious deposition of charcoal in the part of the tube that had been ignited, and the evolved hydrogen was so

* This gas was washed with solution of potassa to separate a little carbonic acid, and was then ascertained to be pure by the action of chlorine, with the precautions afterwards described.

free from carbon, that when detonated with its volume of oxygen, half a volume of the latter remained, which scarcely rendered lime water turbid, and underwent no perceptible diminution by exposure to liquid potassa.

It may be supposed, that in consequence of the dilution of the last portions of olefiant by the hydrogen evolved, the perfect decomposition of the gas is a matter of difficulty, and a trace of carbon will, I believe, always remain in the hydrogen evolved, since the decomposition is progressive. I cannot, however, on this account see reason to believe, with M. BERTHOLLET,* that carbon and hydrogen are capable of forming several definite compounds; the data are, on the contrary, such as to warrant an opposite conclusion.

In making this experiment in the manner just described, and more especially when the tube is only dull red, the first portions of gas that reach the receiving gasometer, are obscured by a considerable quantity of vapour, which, however, afterwards disappeared. To examine more particularly the cause of this phenomenon, I passed some pure olefiant gas, very slowly, through a red hot glass tube, about two feet in length, and containing in the heated part some pure and well burned charcoal: the gas was collected in a cold receiver, the sides of which became lined with a brown viscid substance of an agreeably fragrant odour, perfectly soluble in alcohol, and precipitated from this solution by water, which rendered it turbid, and of a whitish green hue. This peculiar resinous matter appears to be a compound of hydrogen and carbon; its vapour is perfectly decomposed by passing it

* THENARD, Traité de Chimie, Tom. I. p. 293.

through a highly heated platinum tube, hydrogen being evolved and carbon deposited.

5. Mr. FARADAY, whose accuracy as an operator is not inferior to his assiduity as my Assistant in the Laboratory of the Royal Institution, has shown in a paper published in the Quarterly Journal of Science, that the supposed distinction between olefiant and light hydrocarburet, by means of the action of chlorine, has no foundation; and that at common temperature, all varieties of carburetted hydrogen are condensed by, and combine with, chlorine.

To ascertain how far the action of chlorine could be depended upon as a means of analyzing mixtures of olefiant and hydrogen gases, I mixed equal volumes of chlorine and hydrogen, over water at the temperature of 55°, in a tube of half an inch diameter, and exposed to ordinary daylight, but carefully excluded from direct sunshine. After twenty-four hours, the whole of the chlorine had been absorbed by the water, and the original volume of hydrogen remained unaltered.

One volume of hydrogen mixed with one of olefiant gas and two of chlorine, was reduced under the same circumstances to very little more than one volume, the whole of the olefiant having been absorbed.

In these cases it is convenient to use considerable excess of chlorine, and in this way the purity of olefiant gas may be ascertained; it will be found, even when obtained with every caution, to afford a small residue of hydrogen; but as this is sometimes as little as one per cent, it may, generally speaking, be disregarded.

6. The analysis of a mixture of hydrogen with carburetted

hydrogen, carbonic oxide, and carbonic acid, presents peculiar difficulties in the ordinary mode of proceeding; and as it often requires to be performed in investigations relating to the gases used for illumination, it became an object to facilitate the process, for which I have used the following plan.

A hundred measures of the gas are introduced into a graduated tube, and the carbonic acid absorbed by a solution of potassa; the remaining gas is then transferred to thrice its volume of chlorine of known purity, standing over water in a tube of about half an inch diameter, and exposed to daylight, but carefully excluded from the direct solar rays; after twenty-four hours the carburetted hydrogen and the excess of chlorine will have been absorbed, and the remaining gas, consisting of carbonic oxide and hydrogen, may be analysed by detonation with oxygen in excess; the measure of carbonic acid formed being the equivalent of that of the original carbonic oxide.

This proceeding depends upon the non-formation of chloro-carbonic acid in a mixture of carbonic oxide and chlorine in the contact of water, and out of the direct agency of the solar rays. Such mixture I have kept several days, occasionally renewing the chlorine as it became absorbed by the water, and have not observed any diminution in the bulk of the carbonic oxide. In all these cases it is necessary to ascertain the purity of the chlorine by its absorption by water, and to be aware of the evolution of common air from water during that process.

7. I repeated many of the above experiments, substituting for coal gas a mixture of six volumes of hydrogen with five of olefiant gas. The specific gravity of this mixture was,

,4700; one hundred cubical inches weighing 14,2 grains. The flame with which this mixture burned was of the same colour and intensity as that of common coal gas; its dilatation by heat was similar, and it underwent an analogous increase of bulk when heated with sulphur.

The readiness with which carburetted hydrogen is decomposed, when passed through red hot tubes, appears to me to offer a solid objection to a mode of purifying coal gas, which has been proposed by Mr. G. H. PALMER,* since it would deposit carbon, and consequently sustain great loss in illuminating power. The object in view was probably to get rid of the sulphuretted hydrogen; but neither is this so to be attained. In examining coal gas, I have often been struck with the formation of sulphurous acid during its combustion; though when passed through solution of acetate of lead, it occasioned no blackening, a circumstance which led me to suspect the presence of some other sulphureous compound; and I have often thought, in passing the open gas pipes in the streets, that I perceived the smell of sulphuret of carbon. When sulphurous acid or sulphuretted hydrogen are passed with carburetted hydrogen through a red hot tube, a portion of carburet of sulphur is always formed, and the vapour of that highly volatile compound may well exist in the gas employed for illumination, which is always hurried through the condensers and gasometer.

8. Most of the above experiments were now repeated upon the gas obtained by the decomposition of whale oil; its specific gravity was ,7690; so that 100 cubical inches weighed rather more than 23 grains. Deducing the compo-

* PECKSTON, on the Theory and Practice of Gas-lighting, p. 213.

sition of this gas, considered as a mixture of hydrogen and olefiant, from its specific gravity, we should conclude that it is composed of 1 volume of hydrogen and 3 of olefiant, upon the presumption that 100 cubical inches of hydrogen weigh 2,25 grains, and 100 of olefiant 30,15.

Such a mixture, when submitted to the action of heat, of sulphur, and of chlorine, and when detonated with oxygen, afforded results similar to those obtained by experiments upon the original oil gas, and it burned with the same degree of brilliancy.

9. I have also submitted to similar experiments the inflammable gases obtained by the decomposition of acetate of potash, of alcohol, and ether, and by passing water over red hot charcoal. All these contain a considerable portion of carbonic acid, which, when abstracted by potassa, leaves a mixture of carburetted hydrogen, hydrogen, and carbonic oxide, in proportions liable to much variation, according to the materials employed, and to the circumstances under which their decomposition has been effected. The specific gravity of these products is of course liable to corresponding variations.

10. The inference which, I think, may be drawn from the preceding experiments and observations, is, that there exists no definite compound of carbon and hydrogen, except that usually called *olefiant gas*; that the various inflammable compounds employed for the purpose of illumination, and produced by the destructive distillation of coal, oil, &c. consist essentially of a mixture of olefiant gas and hydrogen; that the gas procured from acetate of potash and from moist charcoal contains the same elements, with carbonic oxide and

carbonic acid; and that no other definite compound of carbon and hydrogen can be recognised in them, except olefiant gas.

SECTION II.

Comparative experiments on the illuminating and heating powers of olefiant, coal, and oil gases, and on some general properties of radiant matter.

1. In the following experiments I employed a gasometer with counterpoise weights acting over regulating pullies, and capable of containing about 5000 cubical inches, or about 2,89 cubical feet: the different jets were attached to it in the usual way, and the pressure was measured by the difference in the level of the water within and without the bell, to which was attached an accurately graduated scale sliding through the frame of support.

2. Having filled this gasometer with pure olefiant gas, it was allowed to issue from a brass jet having a single perforation of $\frac{1}{60}$ of an inch diameter, under a pressure of a half inch column of water; it was then inflamed, and regulated by means of a stopcock, so as to produce a light equal to that of a wax candle burning with full brilliancy; the relative intensity of the light of these flames was ascertained by a comparison of shadows. Under these circumstances, the consumption of gas was found $= 640$ cubical inches per hour, or 0,37 cubical feet. When the same burner was used with oil gas, it consumed 800 cubical inches per hour, or $= 0,47$ cubical feet.

3. I now employed an Argand burner, with a cylindrical glass, constructed in the usual way, with 12 holes each of the

same dimensions as that of the single jet, and forming a circle 0,7 inch diameter. The pressure being 0,3 inch, the flame was so regulated as to burn with its full intensity without producing smoke, and its light being measured by a comparison of shadows, it was found equal to ten wax candles. The consumption of gas amounted to 2600 cubical inches, or about a cubical foot and a half per hour.

If the result of this experiment be compared with the above, in which a single jet was used, it will appear, that the proportion of light from a given quantity of gas is increased in a very high ratio by employing many flames near each other, the consumption of the single jet giving a light of one candle, being = 640 cubical inches, whereas the Argand burner gave a light of ten candles, with a consumption not of 640 × 10 cubical inches, but of 2600 cubical inches. It will be remembered, that in the latter, the combustion is perfected by a central current of air, rendered more rapid by the glass tube which surrounds the flame. Count RUMFORD showed some time ago, "that the quantity of light emitted by a given portion of inflammable matter in combustion, is proportional in some high ratio to the elevation of temperature, and that a lamp having many wicks very near each other, so as to communicate heat, burns with infinitely more brilliancy than the Argand's lamps in common use."* The construction of the gas Argand burner is particularly calculated to produce an effect of this kind; and to such a cause the great increase of light relative to the consumption of gas may probably be attributed.†

* DAVY's Elements of Chemical Philosophy, p. 224.

† In the annexed drawing (Plate III.) is represented an Argand burner for oil

4. The gasometer being filled with oil gas, an Argand burner, giving the light of eight wax candles, was found to consume 3900 cubical inches per hour; and the same intensity of light was produced by the same quantity of artificial oil gas; that is, of a mixture of three parts of olefiant and one of hydrogen.

5. The apertures of burners for coal gas require to be considerably larger than those for olefiant or oil gas. In the burner employed in the following experiments, each hole was $\frac{1}{30}$ inch diameter, and the circle upon the circumference of which they were placed, was 0,9 inch diameter. The light of the flame was found equal to five wax candles only, and the consumption of gas per hour amounted to 6560 cubical inches.

With a mixture of six parts by measure of hydrogen with five of olefiant gas, the light of the flame was somewhat more intense; and the quantity of gas consumed by the same burner, so adjusted as not to smoke, was 6000 cubical inches.

6. It appears from the above data, that to produce the light of ten wax candles for one hour, there will be required,

2600 cubical inches of olefiant gas.
4875 - - - oil gas.
13120 - - - coal gas;

gas, upon what I believe to be the most economical construction. The bevilling of the perforated edge contributes greatly to the perfection of the light, as shown in the section, Fig. 1. The diameter of the circle of holes is 0,7 inch, and the holes should not be more than $\frac{1}{30}$ of an inch in diameter. Consuming at the highest average 4000 cubical inches per hour, it gives the light of between eight and nine wax candles of four to the pound.

Fig. 3. is a sketch of what is technically termed a *rose burner*; it has six holes of the same dimensions as those of the Argand, and when so regulated as to produce a light equal to that of six wax candles, its greatest average consumption of gas amounts to 4800 cubical inches per hour.

and that the quantity of oxygen consumed

by the olefiant gas will be = 7800 cubical inches.

by the oil gas - = 11578.

by the coal gas - = 21516.

Olefiant gas cannot of course be employed for any economical purposes, and is only here adverted to for the sake of comparison. The relation of the quantity of oil gas to that of coal gas, furnishes a datum that may be practically useful, especially as indicating the relative sizes of gasometers required for the supply of establishments. It may, I think, be stated with sufficient accuracy for practical purposes, that a gasometer containing 1000 cubical feet of oil gas, is adequate to furnish the same quantity of light as one of 3000 cubical feet of coal gas, provided due attention be paid to the construction of the burners, and to the distribution of the lights.

7. For the ordinary purposes of illumination by oil gas, I consider ten hole Argand burners, each consuming about a cubical foot and a half per hour, and giving the light of seven wax candles, or nearly two oil Argands, as the most economical and generally useful. Single jet burners, or those in which the flames do not coalesce, consume, as has been above shown, a very much larger quantity of gas for the production of an equal quantity of light; and for the same reason, Argand burners, in which the flames do not coalesce, consume more gas for an equal production of light, than those in which the apertures are more numerous, but sufficiently near each other to allow of the union of the separate flames.

8. To ascertain the relative heating powers of the flames of olefiant, oil, and coal gases, I employed the twelve hole Argand burners mentioned above, and placed over each, as near to the lamp glass as was consistent with a clear flame, a

clean copper boiler, 2,5 inches deep and 5 inches diameter, slightly concave at bottom, capable of holding rather more than a quart of water, with an immersed thermometer, and a small vent for steam. It contained two pounds of distilled water, which was raised to the boiling point in similar times, namely, 20′ by each of the flames; so that it would appear, that to raise a quart of water from 50° to 212,° at 30 inches barometrical pressure, requires

870 cubical inches of olefiant gas,
1300 - - oil gas,
2190 - - coal gas.

From this experiment it may be inferred, that the air of a room equally lighted by oil and coal gas, will be much less heated by the former than the latter; but that the actual heating power of the flames is in the direct ratio of the quantity of olefiant gas.

9. Having occasion in some of the foregoing experiments to produce light of great brilliancy by the combustion of olefiant gas, and finding it very difficult to measure its intensity by a comparison of shadows, in the manner pointed out by Count Rumford, I endeavoured to avail myself of Mr. Leslie's photometer; for this purpose I concentrated the light by a plano-convex lens, and placed the blackened ball of the instrument in the focus. I found the effect, however, so great, as to lead me to believe that I had obtained a focus of considerable heating power, and on substituting a delicate mercurial thermometer, it rose 4°,5 in 5′. In the focus thus obtained from the light of a large Argand burner supplied with olefiant gas, the elevation of temperature was very sen-

sible to the hand, and in depressing and elevating the flame by means of a regulating stopcock, corresponding effects were produced upon the thermometer: the lens itself, which was a thick one, did not become heated.

These experiments coincide in result with those of Dr. MAYCOCK, and of M. DELAROCHE,* and show that the calorific rays emanating from common combustibles, are capable of passing through transparent media like those of the sun.

10. There are certain substances, the chemical relations of which are singularly affected by the influence of direct solar rays. Among these, the mixture of chlorine and hydrogen is most remarkable: if kept in common daylight, but out of direct sunshine, the gases do not act upon each other; but the moment the mixture is placed in the sunshine, the muriatic acid begins to be formed. I therefore hoped that this property might be applicable in certain photometrical experiments. I exposed a mixture of equal volumes of chlorine and hydrogen, in a tube inverted over water, capable of holding about four cubical inches, and blown into a thin bulb at its upper extremity, to the brilliant focus produced by a large olefiant gas flame; it was exposed for 15′, but underwent no other change than a slight increase of bulk, acting as an air thermometer.

11. It now occurred to me to try how far any effect would be produced by the more intense light of the Voltaic battery, and I placed the tube containing the mixed gases in a darkened room, within about an inch of the charcoal points connected with an apparatus of one hundred pairs of plates highly

* MURRAY's System of Chemistry, Vol. I. p. 336. 4th. Edition.

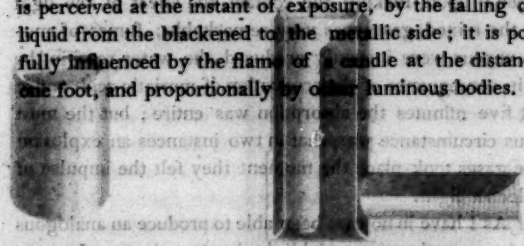
charged: upon making the contact, the effect of the light upon the mixed gases was very remarkable; fumes of muriatic vapour were instantly produced, the water rose in the tube in consequence of the production of muriatic acid, and in about five minutes the absorption was entire; but the most curious circumstance was, that in two instances an explosion of the gases took place the moment they felt the impulse of the electric light.

12. As I have in no case been able to produce an analogous effect by any other terrestrial light, however intense, I cannot but consider the phenomenon as dependent upon some peculiar property belonging to the rays of solar and electric light.

The lunar rays produce no effect upon mixed chlorine and hydrogen, nor upon chloride of silver; neither was the whiteness of the latter in the slightest degree impaired by the most powerful luminous focus that I could obtain from an olefiant gas flame.

13. In some experiments connected with the subjects of this communication, I have availed myself of a photometric thermometer, acting upon the principle of that described by Mr. Leslie, but infinitely more sensible; it is constructed nearly in the same way as the differential thermometer, but instead of containing air, the balls are filled with the vapour of ether, and the stem contains a column of that liquid; it thus forms a very delicate differential thermometer. To convert it into a photometer, the upper bulb is covered with a thin coating of Indian ink, and the lower one with silver or gold leaf; the whole instrument is then placed in a pellucid glass tube: when taken out of its case the influence of light

is perceived at the instant of exposure, by the falling of the liquid from the blackened to the metallic side; it is powerfully influenced by the flame of a candle at the distance of one foot, and proportionally by other luminous bodies.



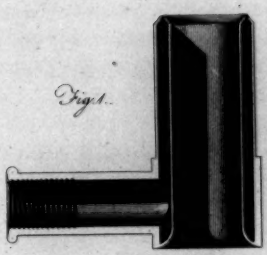


Fig. 1.

Fig. 2.

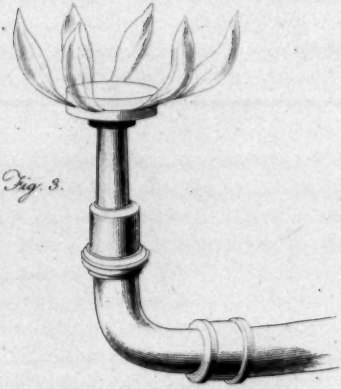


Fig. 3.

III. *On the Elasticity of the Lungs.* By James Carson, *M. D.* *Communicated by* Thomas Young, *M. D. For. Sec. R. S.*

Read Nov. 25, 1819.

In a Treatise which I published a few years ago on the motion of the Blood and the mechanism of Respiration, it was contended, that a cause essential to the performance of these functions, had escaped the notice of physiologists. This cause was stated to be the elasticity or resilience of the lungs. The resilient property of the substance of the lungs had indeed been admitted by all anatomists and physiologists; and it is commonly demonstrated in the lecture room, that, if a piece of the substance of the lungs be cut out and stretched, it will recover its former dimensions when released from the extending power. But though the existence of this property had been universally admitted, no physiologist had attempted, so far as I know, to explain the means by which nature had contrived to render it subservient to the purposes of life. The statement and explication of this contrivance, with reference at least to certain purposes, constitute in a great measure the subject of the treatise to which I have alluded. Although it was proved in that Treatise, that, for the performance of those movements in which life is acknowledged chiefly to consist, a power of considerable extent is derived from the elasticity of the lungs, it was at the same time confessed, that no data had been discovered, from which the full

extent of that power, as it is applied in the living system, could be calculated.

It was conceived that it would be a matter of no small importance to ascertain the extent of a power which, as I believe, discharges a part of the first importance in the scheme of life. With that view, a number of experiments have been performed, which I hope will be found to determine, in a considerable number of animals, the extent of the elasticity possessed by the lungs in their state of expansion in the living and sound body; or the extent of a power by which the heart and diaphragm, and perhaps various other organs, are as necessarily and as effectively influenced as the piston of the steam engine is by the expansive powers of steam.

To enable those Gentlemen who may not be familiar with the anatomy of the parts concerned, to perceive the tendency and import of these experiments, and to understand the arguments that may be advanced, it may be necessary to premise the narration with a short and general description of the structure, position, and connections of the lungs. It is hoped that no person, who has at all applied his attention to mechanical philosophy, will find any difficulty in comprehending this description of a simple but beautiful machinery.

The appearance of the lungs, or, in common language, the lights of oxen and of other animals slaughtered for the use of man, is familiar to every one. They are that irregular pale red spongy mass, which is daily seen suspended in the shambles by the windpipe. The windpipe, or in the language of anatomists, the trachea, which is a necessary appendage to the lungs, extends from the throat to the top of the chest.

It is composed of a succession of cartilaginous rings, which nearly form complete circles. Each ring is connected to the next to it in succession by a strong elastic membrane. A small segment is cut off from each of those rings behind, where the place of cartilage is supplied by the same strong elastic membrane by which the rings are connected. By this contrivance the rings may be expanded, and the diameter of the windpipe is rendered susceptible of variation as well as its axis.

As soon as the windpipe has fairly entered into the confines of the chest, it divides into two branches, one of which proceeds to the right and the other to the left side. These branches possess the same structure with the windpipe itself, and each as it proceeds is divided into smaller branches, which again and again ramify into others still smaller. The branches for some time are formed like the trunk from which they proceed, but at length they drop the cartilaginous structure, and become simply membranous tubes. These tubes ultimately terminate in cells, between which there is a free passage for the air. The interstices between these tubes and cells are filled up by glands, the common cellular substance, and by blood vessels and nerves. The whole of this mass is enveloped in a fine membranous covering, termed the pleura pulmonalis, which however is impervious to the air. To each of the two original divisions of the windpipe a distinct lung is appended, called the right and left, between which there afterwards exists no communication.

The lungs occupy that part of the animal frame denominated the chest. This, in man, is the upper part of the trunk of the body. The shell of the chest is composed of bone,

cartilage, muscular substance, and membrane. Behind, on each side, and in front, it is osseous. It is fenced by the spine behind, by the breast bone in front, and on each side by a tier of ribs, which are connected at one end to the spine by articulations, and at the other end to the breast bone by elastic cartilages. The intercostal muscles secure the spaces between the ribs. The ribs on one side with the corresponding ribs on the other, and with the intervening parts of the spine and breast bone, form the circumferences of so many circles. The circle formed by the junction of one rib with its corresponding rib on the other side, is largest at the bottom, till at the top it is reduced to so small a diameter, as to serve for little more than a passage for the windpipe and gullet. Strong muscles and tendons traversing each other from the upper rib on one side to that on the other, and to the vertebræ of the neck and to the clavicles, and connected by a union of membranes with the exterior surface of the tubes, to which they afford a passage, form the secure boundary of the chest at the top. The form of the chest is evidently conical. The floor or base of this cone is formed by a thin circular plate, partly fleshy and partly membranous, but every where flexible and yielding, with its rim all around firmly concreted with the shell of the chest. It is called the diaphragm or midriff. It cuts the trunk of the body transversely, and separates the cavity of the chest just described from that of the belly. One condition of this flooring is worthy of particular notice. Its area is more extensive than that of the largest transverse section of the chest. In consequence of this, it admits of motion to a considerable extent; and, for reasons which will be afterwards explained, assumes in the

living and sound state of the parts, the form of a cone, of which the apex looks towards the chest.

The form of the diaphragm, or base of the chest, may be illustrated by the comparison of a wine bottle; the bottom of which is convex inwardly and concave outwardly; the diaphragm bearing in form and position the same relation to the chest, which the bottom does to the rest of the bottle.

The cavity above the diaphragm is chiefly filled by the lungs, which therefore in the living system occupy a space nearly as large as the shell of the chest.

As soon, however, as the chest has been opened, and the external surface of the lungs exposed to the contact of the circumambient air, these organs shrink into dimensions far less extensive than those which they occupy in the living body.

The causes of the lungs being expanded in life into larger dimensions than those which are natural to them, or which they occupy when they have been extracted from the body, are curious and important, and may be thus explained.

The walls or boundaries of the chest are well secured. They are at several places indeed perforated by tubes, but these tubes, at the place of their entrance or exit, are, as has been described, always securely concreted by an union of membranes with the substance of the chest. The chief of these perforations are made by the windpipe, the gullet, and some large blood vessels at the top; and at the bottom, by the gullet again in its passage out of the chest, the great descending aorta, and the inferior cava. Conceive then, the lungs to be placed in this cavity in such a manner that the windpipe should pass out of it at the top, having its exterior

surface well secured to the part of the chest at which it passes, but affording, in consequence of its cartilaginous and incompressible structure, an open passage into the interior substance of the lungs, and conceive that no substance should exist between the exterior surface of the lungs, and the internal surface of the chest. The pressure of the atmosphere, it is evident will, in these circumstances, necessarily bring the external surface of the lungs into contact with the whole of the interior surface of the chest; but as the walls of the chest are strong and incompressible, and as the lungs are pliant and dilatable, the lungs are necessarily expanded to the dimensions of the chest, which remain nearly the same. But the lungs, though dilatable, are powerfully elastic; and, when distended to the dimensions which they are thus forced to occupy, their substance is stretched far beyond its natural condition. As soon, however, as the full weight of the atmosphere shall be allowed to ponderate upon the external surface of the lungs, and an equal pressure shall be sustained by their exterior surface and the interior surface of the air vessels, of which their substance is composed, a condition which will arise as soon as the air shall have obtained a free passage through the walls of the chest to the external surface of the lungs; these organs will then shrink into the dimensions which are prescribed to them by the nature of their structure. To ascertain, then, the extent of the power required to distend the lungs to the dimensions which they occupy in the sound system, or, in other words, the extent of that force by which the walls of the chest are pressed, or, in popular language, sucked inwards, in consequence of the resilience of the lungs, is the object of the following experiments.

For the purpose of these experiments, an apparatus of glass, of the following simple construction, was used. An oblong glass globe, containing nearly two quarts, had tubular openings at each end, A, and B. (Plate IV.) A glass tube, nearly three feet in length, and bent at one end, was joined by the blowpipe to the opening at B, and is represented by B, C. To the other opening at A, a shorter tube was joined in the same manner, and in the form A, D. A free passage was established from D to C, where the tubes were both open. To D, a piece of the dried gut of some small animal was bound, of a few inches in length. The other end of the gut was fixed to a cylindrical tube of bone, metal, or wood, also of a few inches in length, and of a diameter corresponding with the diameter of the windpipe of the animal which was to be the subject of the experiment. The windpipe of an animal, which had been recently killed, was divided across near the throat, and separated by dissection from the rest of the neck, nearly to the top of the chest.

The first experiment was made on the 27th of August, 1817, on a cat, which had been hanged the day before. A small cylindrical tube of bone attached by gut to the end of the glass tube, A, D, was inserted into the windpipe, which had been prepared in the way described, and which was tied to the cylinder so tightly, that no air could pass between the external surface of the tube and the internal surface of the windpipe. An open and secure passage was thus established between the glass apparatus and the windpipe, and of course the lungs of the animal. Water was then poured into the apparatus at C, until it stood in the upright tube C, B, at the height of eleven inches above the level of the water in the

glass globe. An opening was then made through the chest of the animal on each side, and the air admitted into contact with the external surface of both lungs. The water instantly sunk about two inches in the upright tube, and the lungs were gently pressed out at the openings. Hence it was inferred, that the spring given to the air by the pressure of a column of water nine inches high, was stronger than the elasticity of this animal's lungs expanded to the dimensions of the chest. To my surprise and disappointment, the water began to sink still lower in the glass tube, and stood at last at the height of an inch above the level of the water in the globe, and the lungs at the same time gradually collapsed. Water was again poured into the upright tube, till it stood for a few seconds at the height of nine inches above its level in the globe, and the lungs again filled the chest. Upon applying the ear to the openings, the cause of the collapse of the lungs was discovered. The sound of air was distinctly heard pressed from the lungs at the openings. Hence it was concluded, that the pleura pulmonalis had been wounded in opening the chest.

On the 28th of August of the same year, a bullock recently slaughtered was made the subject of experiment. The same apparatus, using only a pipe of a larger diameter to be inserted into the larger windpipe of the animal, was applied as in the preceding case. Water was poured into the upright tube at C, until it stood at the height of one foot above the level of the water in the globe, and at that of four inches from the top of the tube. Openings were then made in the chest to admit the air. The water instantly rose in the tube two inches higher, and remained stationary at that point. The

lungs, to appearance, were nearly collapsed to the usual degree. It was evident, from the ascent of the water in the upright tube upon the chest being perforated, that the spring given to the air by being compressed by a column of water twelve inches high, was not sufficient to balance the elasticity of the full dilated lungs of this animal. Water was poured into the apparatus till the tube remained filled. The lungs, with this additional pressure, still continued much shrunk. As the height of the tube was not great enough to ascertain the extent of the pressure necessary to balance the resilience of the lungs of animals of this size in the state of their usual expansion in the living body, an alteration in the apparatus became necessary.

On the 11th of September, 1817, a bullock was made the subject of experiment, with an apparatus of the same kind, but with a taller upright tube. Water was poured into the apparatus till it stood in the upright tube twelve inches above its level in the globe. The thorax was then opened. The water instantly ascended an inch and a half, and remained stationary. More water was then poured into the apparatus; but when it had risen an inch higher in the tube, the globe was found to be full. A further alteration therefore in the apparatus becomes necessary, before the resilience of the fully distended lungs of an ox can be ascertained; for the lungs continued shrunk to a considerable degree, in opposition to the spring of air compressed by a column of water of fourteen inches in height.

On the same day another bullock, with a less capacious chest, was made the subject of experiment with the same apparatus. Water was poured into the apparatus, as in the

preceding instances, till it stood sixteen inches above the level of the water in the globe. An opening was then made into the abdomen. A fold of the fleshy part of the diaphragm was then drawn down on each side, and care being taken that no part of the lung was included in the fold, it was cut into. The sound of a current of air pressing through the openings into the chest was distinctly heard, and the water in the upright tube arose instantly to the height of eighteen inches above the level of the water in the globe. The diaphragm, before the openings, was still tense, and slightly concave towards the belly; but after that it became lax, wrinkled and flat. Some additional water was poured into the apparatus; but we were prevented in this case, as in the preceding, from ascertaining the amount of the force requisite to distend the lungs to the dimensions which they usually occupy in the living animal, by the deficient capacity of the glass globe.

By these experiments, I think it is clearly ascertained, that the spring of air compressed by a column of water of a foot and a half high, is not equal to the resilience of the lungs of an ox, at the usual stage of their dilatation.

In all these experiments, the oxen were placed upon the back with the shoulder raised a little above the rest of the body: some share of the collapsing effort of the lungs might be imputed to their specific gravity. But when the levity of the lungs is considered, and also that they were observed not to shrink more from the breast to the spine than from the diaphragm to the neck, in opposition in this case to gravity, and that their dimensions were not increased, nor their form varied by any change of position; little of the resistance which

the lungs made to the spring of the contained air, is imputable, I think, to their specific gravity.

On the 16th of September, 1817, the apparatus was applied to a calf. When the water in the upright tube had reached the height of fourteen inches above its level in the globe, the lungs appeared to be distended to the full capacity of the chest. Upon cutting off the communication between the apparatus and the animal, the water instantly fell to its level, and the lungs shrunk into very small dimensions. The animal, in this experiment, was placed with the chest erect, so that the shrinking of the lungs upwards from the diaphragm to the neck, and which was observed to be as great as in any other direction, must have taken place in opposition to the specific gravity of the lungs.

In almost every experiment in which the chest was perforated by a sharp instrument, the lungs were found to be wounded, and the object in a great measure defeated. In the experiment about to be described, and the last which will be detailed at this time, great care was taken to prevent the accident now mentioned.

On the 31st of October of the same year, the apparatus was applied to the prepared trachea of a dog, which had been hanged on the preceding day. Water was poured into the apparatus until it stood in the upright tube at the height of six inches above its level in the globe. The abdomen of the animal was opened, and the diaphragm freely exposed. A part of the muscular substance of the diaphragm was drawn down in a fold, which was done without difficulty; and care being taken that no part of the lung was contained in the

fold, an incision was made into it. This was done on both sides. The water ascended instantly about an inch in the upright tube, and the lungs were found to have receded from the openings. Water was poured into the apparatus, until its level in the tube stood above that in the globe at the height of ten inches. The openings in the diaphragm were carefully extended along the chest, and the lungs exposed freely to view. They were now apparently dilated to the boundaries of the chest. In this experiment, the water in the tube remained steadily at the same height, and the lungs continued fully dilated. In those experiments in which the water was observed to descend slowly, and the lungs to collapse gradually, it is very evident, that the lungs must have been wounded, so as to allow some air to escape through the pleura.

The appearance which the lungs exhibited in this situation was novel and interesting, and was no doubt the same which they would have exhibited in the living body, had it been possible to bring them into view. Their surface was smooth and polished, and their edges rounded, without any of those corrugations and sharp angles which they usually exhibit. Their colour was red, and life-like. They felt firm to the touch. The heart appeared like a bird nearly covered by its nest.

The state of the diaphragm in this experiment was worthy of remark. Before the incisions were made into it, it still exhibited a degree of concavity towards the belly, but not with the same degree of tenseness which it is generally observed to possess; for a fold of it was taken with ease,

which in ordinary cases, before the chest has been opened, is done with difficulty. As soon as the openings were made into the diaphragm, it became lax, flat, and corrugated.

Frequent repetitions of these experiments, and much care and accuracy in conducting them, would be required, before the amount of the resilience of the lungs, in all the conditions in which it may be supposed to exist, could be estimated. But defective as these experiments in many respects are, the object, for which they were instituted, seems to have been fully attained by them. In the Inquiry into the causes of the motion of the blood, it was contended, that the elastic substance of the lungs, in consequence of the degree to which that substance was stretched in the living body, generated a permanent power of great extent, and that this power was employed by nature to circulate the blood, and to carry on the process of respiration. The existence of this power was inferred, from the elastic property of the substance of the lungs themselves; from the space which those organs must fill in the living body; from the phenomena exhibited upon opening the chest and admitting the external air; and from the ebullition on the surface of the water into which the inverted windpipe of an animal had been inserted, as soon as the lungs were allowed to collapse. In the various examinations which my opinions have undergone, the existence of this power has been admitted, and the claim to priority in the detection and application of it freely conceded to me: but it has been contended, that the amount of it, in some instances, is inconsiderable, and consequently that the effects ascribed to it have been greatly over-rated. By these experiments, the power has been proved to be greater, than my anticipations even made

it, and fully adequate to all the important offices which I have ventured to assign to it. From a defect in the apparatus, the extent of the power in question could not be ascertained in the lungs of oxen and animals of their size; but it was proved to exceed, considerably, the force necessary to support a column of water of a foot and a half in height above its level. In calves, sheep, and in large dogs, the resiliency of the lungs was found to be balanced by a column of water varying in height from one foot to a foot and a half, and in rabbits and cats, by a column of water varying in height from six to ten inches.

The method by which nature has contrived to apply this powerful engine to the heart and diaphragm, I have attempted to explain at length in the treatise already mentioned. In a preceding part of this paper, however, I have stated, that during the life of the animal, and after death, until an opening shall have been made into the cavity of the chest, the diaphragm assumes the form of a cone, and that the causes of this phenomenon would be afterwards pointed out. The brief explanation which is now to be given of this appearance, will afford, at the same time, a perspicuous view of some of the important purposes to which, in my opinion, nature has turned the elasticity of the lungs.

While the chest is in a sound state, a balance of atmospherical pressure ponderates against the external surface of its walls; or these are pressed inwards more than they are pressed outwards by a given weight. The shell of the chest possesses sufficient stability to resist this pressure without changing in any considerable degree its form and capacity at all parts, except at the base, or diaphragm; which being

muscular, pliant, and of a more extensive area than that of the transverse section of the chest, is in consequence of the greater weight sustained by its outward or inferior surface, necessarily pressed, or, in popular language, sucked upwards in the form of a cone. The extent of this cone will be necessarily regulated by the extent of the area of the diaphragm, compared with that of the area of the transverse section of the chest. But the contraction of the muscular fibres of the diaphragm diminishes its area, and reduces it to a nearer equality with the area of the transverse section of the chest, and thus diminishes the magnitude of the diaphragmatic cone, and in an inverse proportion enlarges the boundaries of the chest. But the diaphragm at the succeeding relaxation of its fibres, is restored to its former dimensions; becomes capable of being swelled into a larger cone; and, by this encroachment, reduces the boundaries of the chest to their former limits.

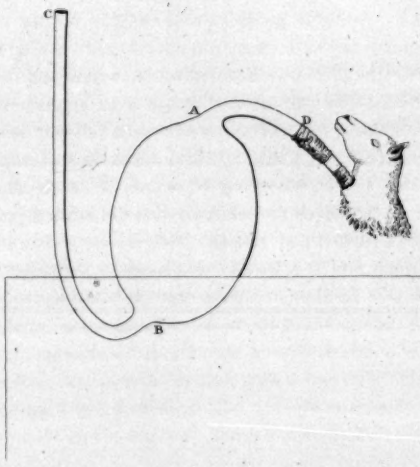
Two powers are therefore concerned in regulating the movements and in varying the dimensions and form of the diaphragm, the elasticity of the lungs, and the contractile power of the muscular fibres of the diaphragm. Of these powers the one is permanent and equable, the other variable and exerted at intervals. The contractile power of the diaphragm, when fully exerted, is evidently much stronger than its antagonist, the resilience of the lungs; but the latter not being subject to exhaustion, takes advantage of the necessary relaxations of the former, and rebounding, like the stone of Sisyphus, recovers its lost ground, and renews the toil of its more powerful opponent.

Breathing is in a great measure the effect of this interminable contest between the elasticity of the lungs and the irritability of the diaphragm.

The cause of the successive contractions of the diaphragm, in those cases at least in which the will is not concerned, seems to admit of the following explanation. A permanent and invariable load is sustained by its lower surface. By this load the relaxed muscular fibres become stretched to a degree which at length becomes painful and stimulating. To relieve itself from this irksome burden, the diaphragm is roused to contraction; but this contractile power, agreeably to the laws of muscularity, is soon exhausted, and falling into a quiescent state, allows the painful and stimulating distension of the relaxed fibres of the diaphragm to be again renewed. From the irksomeness of this condition it relieves itself by a fresh contraction. Thus, by the alternated superiority of two powers, on the balancing of which life itself depends, the chest is successively enlarged and diminished, and air alternately expelled and inhaled.

In a similar and equally effective manner, the elasticity of the lungs will be found to influence the movements of the heart and the motion of the blood. But as these movements are of a more complicated nature; as the consideration of them would lead into a long detail; and as my opinions respecting them are already fully recorded, I will not pursue the inquiry farther at this time.

In investigating the manner in which the elasticity of the lungs is rendered subservient to the great functions of respiration and the circulation, I shall be found, I trust, to have opened to the views of the physiologist, a new and a boundless field, which, I will venture to predict, will reward every skilful and assiduous cultivator with a rich harvest of discovery.


C
A
D
B

IV. *On the action of crystallized bodies on homogeneous light, and on the causes of the deviation from* NEWTON'S *scale in the tints which many of them develope on exposure to a polarised ray. By* J. F. W. HERSCHEL, *Esq. F. R. S. Lond. and Edin.*

Read December 23, 1819.

SINCE the period of the brilliant discovery of MALUS of the polarisation of light by reflection, the investigation of the general laws which regulate the action of crystallized bodies on light, has advanced with a rapidity truly astonishing, and the labours of an ARAGO, a BREWSTER, and a BIOT, have already gone far towards completing the edifice of which that distinguished philosopher laid the foundation. When MALUS wrote, the list of doubly refracting crystals was small, and the most remarkable among them possessing only one axis of double refraction, it seems to have been for some time, tacitly at least, presumed that the law discovered by HUYGENS, and since re-established in the most rigorous manner for that one,* might hold good in all. The discovery, by Dr. BREWSTER, of crystals possessing two axes of double refraction, or two

* The author of the article on Polarisation, in the 63d Number of the Edinburgh Review, just published, is guilty of a most unpardonable mistake, in asserting, (p. 188), as deducible from Dr. BREWSTER'S experiments, that the Huygenian law is *incorrect*, for carbonate of lime. Dr. BREWSTER'S general formulæ for crystals with two axes resolve themselves into the Huygenian law when the axes coincide, of which case it is only an extension. That excellent philosopher, if I understand English, in the paragraph which gave rise to this strange assertion, only means to declare his opinion that it remains undemonstrated.

directions in which a ray may penetrate their substance without separation into distinct pencils, has proved the fallacy of any such generalization, and rendered it necessary to enter on a far more extensive scale of investigation.

There are two methods which may be pursued in observations on double refraction and polarisation, the one direct, the other indirect. The former turns on immediate observations of the angular deviation of the extraordinary pencil, and is, of course, only applicable when the forces which act exclusively on the rays composing it are sufficiently intense to cause a sensible separation of the two pencils. There exist, however, a multitude of crystals in which the force of double refraction is so feeble as to produce scarcely any, or at most a very inconsiderable deviation of the extraordinary ray, and in which, consequently, the laws of double refraction could neither be investigated nor verified, without having recourse to some artificial means of magnifying the quantity to be observed; a thing easy enough in theory, but requiring, in practice, the greatest nicety on the part of the observer, and in many cases altogether impracticable, from the physical constitution of the crystals themselves. The indirect method depends on the discovery of ARAGO, scarcely inferior in intrinsic importance to that of MALUS, of the separation of a polarised ray into complementary portions by the action of a crystallized lamina. It was reserved, however, for the genius of M. BIOT, to trace this striking phenomenon to its ultimate causes, in the action of crystals on the differently coloured rays, and to develope, in a simple and elegant theory, the successive gradations by which the polarisation of a ray in its passage through a doubly refracting crystal is performed;

while, on the other hand, the splendid phenomena of the polarised rings, which we owe to Dr. BREWSTER, have established the connection of the tints so polarised with the force producing the deviation of the extraordinary pencil, and shown the legitimacy of conclusions respecting the intensity of the latter, drawn from observations on the former.

This indirect mode of observation, which consists in noticing the gradations of colour for different positions and thicknesses of the crystal, possesses three capital advantages. The first is its extreme sensibility, which enables us to detect the existence, and measure precisely the intensity of forces, far too feeble to produce any measurable deviation of the extraordinary pencil. It, in fact, affords the rare combination of an almost indefinite enlargement of our scale of measurement, with a possibility of applying it precisely to the object measured, arising from the distinctness of all its parts. Another, no less precious, is the leading us by mere ocular inspection to the *laws* of very complicated phenomena, and enabling us to form, and mould as it were our analytical formulæ, not on a laborious, and sometimes deceptive discussion of tabulated measures, but on the actual form of the curves themselves, which are loci of the functions under consideration. It is true, that a reference to tabulated measures is indispensible to give precision to such first approximations; but the power this mode of observation affords of copying our outline fresh from nature, and from the general impression of the phenomena, brought at once under our view, is an advantage not to be despised. Nor ought we, lastly, to omit, in our estimate of advantages, the means thus afforded us of subjecting the minutest fragments of a crystal to a scrutiny as

severe as the most splendid specimen, and thus extending our researches to an infinitely greater variety of natural bodies, than we could otherwise hope to examine.

In order, however, to render observations on the tints developed by polarised light available, they must be comparable to each other; and it therefore becomes an object of the first importance, to ascertain the existence, and discover the laws of any causes which may operate to disturb their regularity. Ever since I first engaged in experimental enquiries on the polarisation of light, I was struck by the very considerable deviation from the succession of colours in thin laminæ, as observed by NEWTON, which many crystals exhibit when cut into plates perpendicular to one of their axes. I at first attributed this to a want of perfect regularity in their structure, or to inequalities in their thickness, arising from my own inexpertness in grinding and polishing their surfaces; and it was not till habit had rendered me familiar with all the usual causes of deception, that, finding the same phenomena uniformly repeated in different and perfect specimens, my curiosity became excited to enquire into their cause, the more so, as they now began to assume the form of a radical and unanswerable objection to the theory of M. BIOT, above alluded to, which affords so perfect an explanation of the tints in crystals with one axis.

These phenomena have not escaped the vigilance of Dr. BREWSTER. In his paper of 1818, he distinctly notices the fact of a deviation from NEWTON's scale, in crystals with two axes, and promises a more detailed account of it, which however has not yet appeared. But the object of the present communication is not thereby anticipated, as in the only passage in that paper

in which he expresses himself otherwise than obscurely on its cause, he appears to regard the deviated tints as analogous to those developed along the axis of rock crystal and by certain liquids; an analogy which, in the present state of our knowledge on that perplexing subject, it seems not easy to admit. In a paper too, which has lately appeared, containing the interesting observations of the same excellent philosopher on the optical structure of the apophyllite, he remarks the very striking deviation of the colours of this crystal from NEWTON's scale "in the first orders" of its rings; and while he remarks that such deviations are common enough, and indeed universal in crystals "in which the rings are formed by the joint action of two axes," seems to think this analogy close enough to authorize the substitution of two rectangular axes of a negative character for the single positive axis actually observed, according to his own peculiar and ingenious views on this subject. I lost no time in endeavouring to procure a specimen of this mineral, and by the kindness of my friend, Sir SAMUEL YOUNG, (to whom I owe more than one obligation of this nature) was favoured with one sufficiently transparent for optical examination. From my observations on this body, I think I shall be able to demonstrate satisfactorily, that the phenomena of the apophyllite depend on a principle distinct from that which produces the chief part of the deviation of tints in most crystals with two axes.

The course I propose to pursue is, first, to describe the phenomena themselves. I shall then show how these phenomena, complicated as they are in appearance, are all reducible to one very simple and general fact; viz. that the axes

of double refraction differ in their position in the same crystal for the differently coloured rays of the spectrum, being dispersed in one plane over an angle more or less considerable, according to the nature of the substance. In many bodies, the magnitude of this dispersion of the axes is comparatively trifling, while in some, not otherwise remarkable for a high ordinary or extraordinary dispersive power, it is enormous, and must render all computation of the tints in which it is not taken into consideration, completely erroneous; and indeed obliterating almost every trace of the Newtonian scale of colour. We have here, then, a new element, which for the future must enter into all formulæ of double refraction pretending to rigour, and at the same time are presented with another very striking instance of the inherent distinction between the differently coloured molecules of light, which, since the time of NEWTON, every new step in optical science has tended to place in a stronger point of view. At the same time, by the easy and complete explanation this principle affords of all the more perplexing anomalies in the tints, the theory of alternate polarisation to which they were hitherto so palpable and formidable an objection, stands relieved from every difficulty, and may now be received as fully adequate to the representation of all the phenomena of the polarised rings, and entitled to rank with the fits of easy transmission and reflection, as a general and simple physical law. In fact, if we investigate by this theory a general analytical expression of the tint developed for any position and thickness of the plate, taking this element into consideration, it will be found to include all the phenomena, as far as they can be computed,

while the *law* ofdispersion remains unknown. But we may go yet farther. The nature of the formula furnishes an equation by which the actual quantity of the separation of the extreme red and violet axes may be deduced from observations of the tints of a very simple and accurate nature, being perfectly analogous in principle to the "method of coincidences," which has of late been applied with such success to the most delicate investigations in every department of physical science. The comparison of the results afforded by that equation, with those deduced by direct observation on homogeneous light, while it leaves nothing to desire in point of accuracy, leads to another important result, viz. that the proportionality of the minimum lengths of the periods performed by differently coloured molecules, in a doubly refracting crystal to the lengths of their fits of easy reflection and transmission, supported as it is by an induction of no ordinary extent and accuracy, is yet not universal, admitting a deviation to a very large amount. Hence must of course arise a kind of secondary deviation in the scale of tints. In crystals with two axes, however, this is masked by the much more powerful effect of the separation of the coloured axes; yet even there, is not altogether insensible in an extreme case. In the apophyllite, however, the agency of this secondary cause is placed in the fullest evidence. The application of our general formula to the anomalous tints of that body, while it proves incontestably the exact coincidence of the axes for all the coloured rays, points out at the same time a peculiarity in its action on the more refrangible extremity of the spectrum, of a nature so singular, so entirely without example in all the multitude of

natural and artificial bodies hitherto examined, as to render me extremely desirous of prosecuting the research, with the aid of more perfect specimens, and improved methods of observation.

Having arrived at the general result of a dispersion of the axes by the sole consideration of the gradation of tints in plates of various thicknesses, it becomes interesting to verify it by direct and independent observation. This I have accordingly done; and the fortunate discovery of a substance in which it is of enormous magnitude, puts it in our power to render the fact sensible to the eye of the most unpractised observer, by an exceedingly simple experiment, to be described in its place.

II. *Of the general phenomena of crystals which develope tints deviating from* NEWTON'S *scale, by exposure to polarised light.*

In describing the phenomena, I shall at present confine myself to the tints developed along the principal section of the crystal, which is supposed placed in an azimuth 45° with the plane of primitive polarisation. The observations of the tints in this position are most easily made, and least liable to error, and we shall see presently that it would be superfluous as well as embarrassing to examine other situations, the law of the phenomena being completely deducible from this. In this series of observations, then, we traverse the polarised rings (Pl. V. fig. 1.) in the direction of their axis of symmetry AA′, passing through their poles P,P′ and centre O. Now if we subject to this examination any one of the following substances:

Sulphate of soda ? Arragonite,
Sulphate of baryta, Sugar,
Nitrate of potash, Hyposulphite of strontia,

it will be seen that the tints between the poles PP′ correspond to lower orders of colour, than would result from assuming P, P′, as the origin of the scale, and agree much better with the assumption of certain points p, p' without the poles, as their zero, or commencement of the scale. The poles themselves, too, instead of being absolutely black, are tinged with colour; and the tints beyond them, instead of descending in the scale from the poles outwards, continue to rise till they reach their maximum (which is a white, more or less brilliant, or an absolute black) at the points p, p'; after which they descend again to infinity. Not that in any case they coincide precisely with the scale of NEWTON, even with this correction, but, except in extreme cases, approximate to it within some moderate limit of error.

If, on the other hand, we examine in the same manner one of the following bodies:

Tartrate of soda and potash, Sulphate of magnesia,
Borax, Topaz,
Mica,

it will be found that the imaginary points p, p' (which we shall call the *virtual poles*) from which the tints must be reckoned inwards and outwards, to produce the nearest possible agreement with NEWTON's scale, lie between the poles P, P′.

In all these crystals, as the thickness of the plate examined increases, the virtual poles pp' recede from the actual ones PP′, at least in respect of the number of alternations of colour which intervene between them: in other words, the tint deve-

loped in the poles, or along the apparent axes of the crystal, descends in the scale of colour, as the thickness of the plate increases, and *vice versa*. In very small thicknesses, the tints approximate pretty closely to NEWTON's scale, or wholly coincide with it, while in very great ones, the tint developed in the poles is the composite white of the extremity of the scale. The angular distance, however, of the virtual poles from each other and from the axes, remains absolutely unchanged for all thicknesses; and this striking fact, which I have proved by numerous and satisfactory experiments, was first suggested for examination as a result of theory, and would equally hold good, as will presently be proved, for every conceivable law of double refraction.

The substances which I have examined most attentively, are sulphate of baryta, nitre, mica, and Rochelle salt, and the subjoined tables of tints developed for different inclinations in plates of the first and last of these, may serve as examples of the mode of action of the respective classes to which they belong on light, and will afford data for some calculations to follow. The first two columns contain the inclinations corresponding to similar tints of the incident ray on the moveable plate which carries the crystal, in the general apparatus imagined by M. BIOT, for observations of this kind. Were the plate cut in a direction precisely perpendicular to the optic axis, (or line bisecting the angle between those of double refraction) and adjusted with perfect accuracy on the instrument, the excesses or defects of these angles above or below 90° would represent the angles of incidence. Neither of these conditions were, of course, exactly fulfilled. But it is obvious that the small errors in these particulars (which

were ascertained not to exceed 1° or 2°), must affect the computed angles of refraction on both sides of the perpendicular with equal and opposite errors. The same may be said of any error arising from a slight prismaticity of the plate, which, however, must have been extremely small, the plate having always been rendered parallel by the delicate test of the sphærometer, within a very few divisions.* Consequently, in calculating on these data, the mean angle of refraction determined by the simultaneous use of both observations, (their semi-difference being taken for the angle of incidence) may be expected to differ from the truth by an extremely minute quantity. The third column contains the tint developed in the ordinary pencil, and the fourth in the extraordinary. The last notices the remarkable points in the system of rings to which the tints and angles in the other columns correspond. The positions of the poles were determined by interposing a red glass between the crystal examined and the reflector used to polarise the incident light. The glass used for this purpose, was of that kind occasionally found in old church windows, and whose manufacture seems to be numbered among arts now forgotten. It transmits almost the whole of the red rays, and part of the orange, while it completely stops all the more refrangible colours. I have endeavoured in vain to procure a specimen, whose limits of transmission are more confined. Such are said to exist, though very rare, and in the absence of such, the indications of that employed may be taken to correspond to the mean red rays.

* Each equal to the 23809th part of an inch.

TABLE I. *Sulphate of baryta. Thickness of plate* = 0.11964 in.

Corresponding inclinations.				Ordinary pencil.	Extraordinary.	Remarks, &c.
°	′	°	′			
43	55	134	37	Pink	Very pale blue green	Tints beyond the poles.
45	0	133	42	Bluish green	Pink	
46	0	132	45	Rich pink	Beautiful green	
		132	0	Whitish	Dull purple	
46	58	131	37	Splendid green	Rich crimson	
		131	0	Blue	Yellow	
47	53	130	45	Crimson	Fine green	
				Yellow inclining to orange	Blue	
				Yellow	Purple	
48	51	129	30	Blue green	Rich crimson	
				Blue	Orange	
		128	58	Purple	Pale yellow	
				Rich crimson red	Pale green or greenish white	
				Fine orange	Light blue	
				Pale orange yellow	Dark blue	
50	58	127	45	White	Sombre & very narrow purple	
				Bluish white	Scarlet or fiery red	
				Light blue	Orange	
				Sombre greenish blue	Ruddy white, or very pale	
52	0	126	50	Dirty and very sombre purple	White [orange	
				Sombre and narrow pinkish red	White	
				Very pale violet or pinkish white	Greenish white	
				White	Dirty bluish green	
53	1	125	47	White	Narrow and very sombre violet	Virtual poles
		125	30	White slightly yellowish	Violet [purple	pp′, or points
		125	0	Pale and dirty olive green	Violet white	of coincidence.
				Very narrow violet	White	
54	8	124	30	Blue very sombre and narrow	White slightly yellowish	
				Light blue	Pale yellow	
				Bluish or greenish white	Indifferent purplish pink	
55	25	123	30	Yellowish white	Sombre and narrow purple	
				Light yellow	Dark blue	
				Dull orange pink	Pale greenish blue	
56	33	122	15	Sombre purple	Pale yellow green	
				Blue	Yellow	
57	30			Pale green	Fine pink verging to crimson	
57	50	121	0	Pale yellow	Purple	
58	15	120	15	Light yellowish pink	Greenish blue	The poles P, P′
				Rich pink	Bluish green	Tints between
59	12	119	35	Pale purple	Greenish white	the axes.
				Blue green	Crimson	
60	45	118	20	White	Very pale purple	
		117	40	Pink	Blue green	
62	0	117	5	Pale purple	Whitish	
62	58	116	25	Greenish blue	Pink	
63	25	115	35	White	Dull purple	
64	28	114	47	Pink	Bluish green	
65	40	113	20	Greenish blue	Pink	
67	30	111	30	Pink	Pale greenish blue	
69	15	110	0	Pale greenish blue	Pale pink	

In this plate the virtual poles correspond very nearly to the second minimum of the extraordinary pencil beyond the poles PP′. The same plate was now reduced by grinding to the thickness 0.08816 inches. In this operation, care was taken to grind away the side of the plate most distant from the eye only, leaving the other perfectly untouched and unimpaired in its polish. The plate being reduced to exact parallelism by the sphærometer, was again examined, the same side still remaining next the eye. By this arrangement the same angles of emergence from the posterior surface correspond rigorously to the same directions of the ray in the interior of the crystal, with respect to the axes of its molecules; and thus we avoid completely any errors which might arise from using plates cut at different angles, it being almost impossible to cut two plates precisely alike in this respect.

TABLE II. *Sulphate of baryta.* *Thickness* $= 0.08816$ in.

Corresponding inclinations.				Ordinary pencil.	Extraordinary.	Remarks, &c.
°	′	°	′			
58	0	120	0	Pink, verging to orange yellow	Blue somewhat greenish	Poles for the mean red rays.
				Yellow	Dark blue	
57	30	120	47	Pale yellow	Purple	
				Greenish white	Pink	Tints beyond the poles.
				Light blue	Yellow verging to orange	
				Dark blue	Bright yellow	
55	57	122	15	Sombre purple	Yellow white	
				Very indifferent sombre pink	Bluish white	
				Pale yellow	Dark indigo blue	
54	5	124	0	White	Sombre violet	
				Very pale violet white	Dusky greenish yellow	
52	57	125	33	Very sombre violet, almost black	Pure brilliant white	Virtual poles.
				Sombre and dirty olive green	White rather ruddy	
				Very pale blue	Orange white	
				White	Sombre orange or brick red	
51	30	127	0	White	Narrow purple	
				Orange white	Blue	
				Bright orange	Pale blue	
				Bright scarlet	Bluish white	
				Narrow crimson	White	
50	0	128	30	Purple	White	
				Blue	Yellow	
				Bluish white	Rich crimson	
48	40	130	0	Yellowish or greenish white	Purple	
				Orange yellow	Bright blue	
47	35	131	10	Rich crimson	Green	
47	10	131	28	Purple	Good yellow	
				Bright blue	Pink yellow	
46	7	132	33	Good green	Rich pink or crimson	
45	3	133	45	Rich pink	Splendid green	
44	33	134	30	Greenish purple	Pinkish white	
43	35	135	15	Good green, but pale	Fine pink	
42	23	136	30	Pink red	Greenish blue	
40	55	138	0	Pale bluish green	Pale pink	
39	30	139	50	Pale pink	Very pale greenish blue	

In this plate the virtual poles correspond to the second maximum of the extraordinary pencil. It is needless to detail the tints between the poles. The same plate once more reduced, with the same precaution to leave the posterior surface untouched, developed the following series of colours beyond the poles.

TABLE III. *Sulphate of baryta. Thickness* = 0.05758 in.

Corresponding inclinations.				Ordinary pencil.	Extraordinary.	Remarks, &c.
°	′	°	′			
60	57	122	50	Fine yellow	Indigo	Poles, for the mean red rays.
60	20	123	27	Pale yellow	Purple	
				White inclining to yellow	Dull crimson red	Tints beyond the poles.
				Bluish white	Dull orange	
				Indigo	Yellow	
57	55	126	3	Sombre purple	White	
57	50	126	7	Sombre reddish violet	White	
57	20	126	33	Dirty violet yellow	White	
		127	30	Pale yellow	Violet white	
55	40	128	2	White	Sombre violet	
55	33	128	20	Pure brilliant white	Black	Virtual poles.
		128	30	White	Sombre dirty green	
				Pale orange	Pale dirty bluish green	
53	40	130	10	Sombre orange or brick red	White	
53	27	130	30	Sombre and narrow purple	White	
				Blue	Ruddy white	
				Pale blue	Orange	
				Bluish white	Orange red	
		132	20	White	Narrow crimson	
51	3	132	40	Pale yellow, &c. &c.	Purple, &c. &c.	

Here the virtual poles p, p' correspond precisely to the first minimum of the extraordinary pencil.

In a plate of Rochelle salt, cut nearly, but not quite perpendicular to the optic axis, and whose thickness was 0.194425 inches, the rings beyond the poles were almost entirely obliterated, while those between them exhibited the following singular succession of colours, which will show to what an extent the deviation from NEWTON's scale is carried in this substance.

TABLE IV. *Rochelle salt, perpendicular to the optic axis. Thickness*=0.194425 in.

Corresponding inclinations.				Ordinary pencil.	Extraordinary.	Remarks, &c.
°	′	°	′			
201	30	330	10	White	White	Poles PP′ for red rays.
207	10			Exceeding pale blue	Exceeding pale pink	
209	0			Exceeding pale pink	Exceeding pale blue	
210	30			Very pale blue	Very pale pink	
212	30			Very pale pink	Very pale blue	
213	20			Very pale blue	Very pale pink	
215	25			Pale pink	Pale blue green	
216	40			Pale blue	Pale yellow pink	
218	0			Pink	Blue green	
219	29			Pale blue	Pale yellow pink	
220	58			Pink	Greenish blue	
				White	Very pale purple	
222	30			Blue	Yellow pink	
223	45	309	30	Yellowish pink	Greenish blue	
224	50	308	15	Pale greenish blue	Yellowish pink	
				Blue	Pale pinkish yellow	
226	10	307	0	Pale pink	Pale greenish blue	
		306	10	Pale yellow	Dark blue	
				White	Pale purple	
227	25			Bluish or greenish white	Very pale violet pink	
228	30			Blue	Very pale yellow	
				Violet almost impereceptible	White	
229	3	304	10	Pure white	Pure white	Virtual poles *p*, *p*′.
				Exceeding pale yellow	A little violet	
229	50			Pale yellow	Very narrow dark blue	
				Very pale tawny orange	Blue, sombre and pale	
231	20	302	20	Fine purplish crimson	Pale yellow green	
				Very pale purple	White	
232	25			Very pale green	Fine crimson	
				White	Pale purple	
234	0	299	20	Splendid crimson	Very pale green	
				Pale purple	White	
235	40			Very pale green	Rich crimson	
				White	Pale purple	
236	23	296	15	Rich crimson	Very pale green	
				Pale purple	White	
238	50	294	35	Pale blue green	Good pink, almost crimson	
				White	Very pale purple	
240	12	292	55	Pink rather pale	Pale greenish blue	
				White	White	
242	10	291	30	Pale blue	Pale yellowish pink	
243	40	289	50	Pale pink yellow	Pale blue	
245	10	287	45	Very pale blue	Very pale yellow	
246	50	286	45	Very pale yellow green	Very pale lilac blue	
248	25	284	55	Pale lilac	Yellow green	
				White	White	
250	40	282	30	Fine yellow green	Fine lilac	
				White	White	
252	57	280	12	Lilac	Fine yellow green	
				White	White	
256	5	277	25	Fine yellow green	Fine lilac	
				White	White	
259	20	274	40	Pale lilac	Fine yellow green	
261	40	271	40	White	White	
266	40	266	40	Green yellow	Pale lilac	The middle tint

In order however to avoid the effect of the dispersive power, which at such considerable obliquities would render the observations liable to some uncertainty, I cut another plate, in such a manner that the perpendicular to its surface, instead of coinciding nearly with the optic axis, was directed very nearly to one of the virtual poles. Its thickness was then gradually reduced in the manner above described for sulphate of baryta, though, owing to the nature of the body, it was found impossible to avoid the necessity of re-polishing the posterior surface at each operation; but as this was done with all possible care, only a very slight error can have arisen from this cause.

TABLE V. *Rochelle salt.* *Thickness* = 0.11518 in.

Inclinations.	Ordinary pencil.	Extraordinary.	Remarks, &c.
° ′			
277 8	Very pale pink	Very pale bluish green	Pole P for mean red rays.
261 8			Perpendicular incidence.
261 0	White tinged with orange	Very fine intense indigo	
260 25	Yellowish or greenish white	Purple rather sombre	
259 45	Very pale greenish blue	Indifferent purplish pink	
	Dull blue	Yellowish pink white	
258 50	Fine deep indigo	White inclining to orange	
258 30	Violet purple	Yellowish white	
257 35	White, a little tinged with violet	White, not very brilliant	The virtual pole *p*.
	Yellowish white	Pale violet blue	
256 30	Pale yellow	Sombre indigo inclining to violet, narrow & well defined.	
	Pale pink yellow	Sombre violet white	
255 10	Pinkish purple	Very pale greenish yellow	
154 30	Rich sombre purple somewhat fiery	White tinged with greenish yellow	
	Pale green	Fine crimson [low	
252 30	Extremely pale green	The richest deep damask crim-	
	White	Livid imperfect purple [son	
250 27	The richest damask crimson	Fine pale green	
	Livid imperfect purple	White	
248 5	Pale bluish green	Fine rich crimson	
245 45	Pink approaching to red	Pale blue green	
243 30	Sky blue	Light pink strongly inclining to	
240 25	Pink orange	Pale greenish blue [orange red	
	Sky blue inclining to lilac	Fine yellow	
237 30	Pale bluish green	Fine pink a little purple	
237 0	Splendid yellow green	Lilac	
234 20	Rich lilac	Splendid green	
230 10	Splendid green	Rich lilac	
	White	White	
225 45	Lilac blue	Splendid yellow green	
	White	White	
220 40	Splendid green yellow	Pale lilac blue	
	White	White	
211 40	Pale lilac	Pale greenish yellow	
197 20	Fine yellow green	Fine lilac	

Here the virtual pole was coincident with the 5th maximum (or thereabouts) of the extraordinary ray from the pole P; the succession of tints, however, unless close to the virtual pole, is omitted, in order to shorten the table.

TABLE VI. *Rochelle salt.* *Thickness* = 0.08557 in.

Inclinations.	Ordinary pencil.	Extraordinary.	Remarks, &c.
° ′			
202 0	Good light pink	Light blue green	Pole P for mean red.
278 0	. . . . .	. . . . .	Perpendicular incidence.
	Very pale yellow green	Bluish purple	
278 20	Very pale yellow green	Violet	
278 55	Very pale bluish green	Very light pink, or pinkish white	
280 0	Indigo	Very pale yellow, almost white	
	Pale violet	Very pale yellow	
281 30	White	White, perfectly equal and alike	Virtual pole.
	Very pale greenish yellow	Pale lilac	
282 35	Pale greenish yellow	Sombre lilac purple	
	Pale pinkish yellow	Dull and impure blue	
	Pale pink	Pale yellow green	
285 15	Crimson	Yellow green	
285 45	Rich fiery damask crimson	Very pale yellow green	
	Livid imperfect purple	Very pale pink yellow	
287 50	Fine light green	Fine pink	
288 45	Very pale green	Splendid crimson	
	Good crimson	Blue green	
291 40	Crimson, almost scarlet, &c.	Pale blue green, &c.	

In this plate the virtual pole fell about half way between the 4th maximum and the 5th minimum of the extraordinary ray from the apparent pole P for the mean red rays. When once more ground down, it gave as follows:

TABLE VII. *Rochelle salt. Thickness* = 0.05487 in.

Inclinations.	Ordinary pencil.	Extraordinary.	Remarks, &c.
° ′			
262 25	Fine pink	Fine light blue green	Pole? for mean red rays.
277 20	Indifferent lilac pink	Very pale greenish yellow	
278 25	Pale yellow inclining to orange	Blue rather pale	Perpendicular incidence.
	Fine pale yellow	Beautiful sombre indigo	
280 50	Yellowish white or pale yellow	Violet	
282 0	White	White with an almost imperceptible tinge between yellow and violet	Virtual pole
	Very pale blue	Yellow white	
284 50	Sombre indigo	Pale yellow white	
	Very pale blue	Extremely pale pink white	
	Yellow green	Lilac pink	
	Pale yellow green	Deep lilac pink	
288 25	Greenish white	Rich but sombre purplish crimson	
	White	Dull purple	
	Very pale pink	Good blue green	
293 33	Deep fiery crimson	White	
	Very dull purple (greenish)	White	
	Blue	Pink yellow &c.	
294 50	Very pale blue, &c.	Rich orange, bordering on red.	

III. *On the causes of these phenomena.*

The developement of colour along the axis of double refraction, is at first sight analogous to the production of the secondary tints along the axis of rock crystal, discovered by M. ARAGO, and recently explained by M. BIOT, in a masterly memoir communicated to the Academy of Sciences, on the hypothesis of a force inherent in its molecules independent of their state of aggregation, by which they communicate a rotation in an invariable direction to the axes of polarisation of the luminous rays. And this analogy is partially supported by the fact, that the tint developed along the axis, descends in the scale of colour as the thickness increases.

A more scrupulous examination however will show, that its origin must not be sought in any cause of this nature, for (not to mention the impossibility of explaining the phenomena of the virtual poles by this hypothesis) if we place the principal section of the crystal in the azimuth zero, the extraordinary image will be found to vanish completely for every angle of incidence, and whatever be the thickness of the plate. I may add too, that I have in my possession a crystal of quartz, which exhibits with tolerable distinctness in some parts the phenomena of two axes, and the appearances produced by the interference of the secondary tints in this specimen, while they agree completely with M. Biot's explanation, differ entirely from those which form the subject of this Paper.

Neither are the phenomena above described explicable on any supposition of a peculiar action of the crystal on the differently coloured rays, analogous to its ordinary or extraordinary dispersive power, by which the periods of alternate polarisation of the molecules of some colours, should be lengthened, and of others contracted, so as to disturb that exact proportionality to their periods of easy reflection and transmission, which M. Biot has proved to be a necessary condition for the production of the tints of Newton's scale. It is true, such laws of action may be imagined, and I shall presently show must really exist; in all crystals probably to a small extent, but in two instances at least, to a surprising degree. But this alone will avail us nothing. To show this, and at the same time obtain a general analytical expression for the tint developed at any inclination, and for every hypothesis of the action of the crystal on the differently coloured molecules, let us denote by c, the length of a complete period of easy

transmission and reflection, or the extent of one pulse, on the undulatory hypothesis, in vacuo, and at a perpendicular incidence for any homogeneous ray, and let C denote its colour and proportional intensity or illuminating power in the prismatic spectrum. Then will the formula representing a beam of white light intromitted into the crystal, be

$$C + C' + C'' + \&c.$$

from one end of the spectrum to the other.

Let n be the number of periods (each consisting of a double alternation) and parts of a period performed by the elementary pencil C, in its passage through the medium: then, according to the theory of M. BIOT, when n is $0, 1, 2, 3$, &c. ad inf. the pencil will wholly pass into the ordinary image; but when the values of n are $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}$, &c. it will wholly* be thrown into the extraordinary one, and in the intermediate states of n, partly into one and partly into the other. These conditions are satisfied if we represent by $\sin.^2(n\pi)$ the intensity of the ray in the ordinary image, taking unity for its original intensity; and it will I believe be found, that the gradation of intensity given by this formula for the inter-

* The amplitude or total extent of each oscillation of the plane of polarisation is here supposed 90°, in which case the contrast of colour in the two pencils is at its maximum. This is the case in the situation we are considering, but in general the intensity of the extraordinary ray, instead of being represented by $\sin.^2 n\pi$, will have an additional factor, a function of the azimuth A of the principal section of the crystallized plate and the position of the refracted ray, and which becomes unity when A=45°, and the plane of incidence is that of the principal section. It is on this factor that the gradation of *brightness* in the isochromatic lines, and the black cross or hyperbolic branches which intersect them, depend. But it is not my intention at present to enter on this part of the subject for reasons to be explained farther on. See note in page 84.

mediate values of n, will agree sufficiently with the judgment of the eye to warrant its adoption.* The part of the elementary pencil C then, which enters into the extraordinary image, will be $C.\sin^2(n\pi)$. Let us denote by $S\{C.\sin^2(n\pi)\}$ the aggregate of all such elements from one extremity of the spectrum to the other, or take

$$S\{C.\sin^2(n\pi)\} = C.\sin^2(n\pi) + C'.\sin^2(n'\pi) + \&c.$$

Then will this expression represent the tint developed in the extraordinary image, and consequently, $S\{C.\cos^2(n\pi)\}$ that in the ordinary one.

Now, n, the number of periods performed depends, 1st. on the nature of the ray, or on c; 2dly, on the intrinsic energy of the action of the medium on that ray; and 3dly, on the direction of its course, the thickness of the plate, and whatever other cause or limit of periodicity may happen to prevail. Hence we may take $n = M \times k$, k being a function of c, dependent only on the nature of the body through which the ray C passes, and M being a certain multiplier whose form we shall consider presently. This substitution made, the expression for the tint becomes $S\{C.\sin^2(Mk.\pi)\}$

In the theory of the Newtonian colours of thin plates and the polarised rings in crystals with one axis, the multiplier M is independent on c, varying only with the direction of the ray and the thickness of the plate. It is therefore the same for all the coloured rays, and the tint, for any value of M, will be

* No part of our subsequent reasoning depends on the *form* of this function. It is sufficient to know that it must be a periodical, and even function of n. It is only in the computation of numerical values that it is necessary to make any more precise assumption.

$$C.\sin^2(M k \pi) + C'.\sin^2(M k' \pi) + \&c. \qquad (a)$$

Now, suppose M to begin from zero, and to pass, by a variation either in the direction of the ray or thickness of the medium, or both, through all gradations of value, to infinity, or to its maximum, if not susceptible of infinite increase: then we see that for every value of M a certain peculiar tint will arise, and that, provided M commence at zero and continue increasing, the same succession of tints will invariably be developed in the same order. Consequently, if we fix upon any two tints in this scale of colour, or any two values of M, the same succession and the same number of alternations of colour must invariably intervene between them, however we pass from one to the other.

In a crystal with two or more axes, the value of M for any ray C must of course be zero in the direction of the axis, and therefore if the same supposition of the independence of M on c be made, the same conclusions should follow; namely, 1st. that the extraordinary ray must always vanish in the pole, whatever be the thickness of the plate; and 2dly, that the same succession and number of alternations of colour should intervene between the pole and any assigned unequivocal tint, such as black, or the pure brilliant green of the 3d order of NEWTON's scale. Both these conclusions are totally at variance with the facts above detailed, as to the developement of colour in the poles, and the situation in the order of the rings of what we have called the virtual poles. Hence we are necessitated either to give up the theory of alternate polarisation altogether, or to admit the dependence of the multiplier M on c, or on the nature of the ray. Let us see to what this will lead us.

According to the theory of the polarised rings if extended to crystals with two axes, the number of periods performed in a given space ($=1$) by a molecule of a given colour, transmitted in a direction making angles θ, θ' with the axes, can only be a function of the form $k.\psi(\theta, \theta')$, k depending on the intensity of the polarising force; or as before, being a function of c, the nature of the ray, and of the intrinsic energy of the molecules of the crystal. Now if we call t the thickness of the plate, and φ the angle of refraction, $\frac{t}{\cos\varphi}$ is the length of the path described, and therefore we must have for the number of periods

$$n = \frac{k\,t}{\cos\varphi} \cdot \psi(\theta, \theta') ;$$

so that the value of M must be $\frac{t.\psi(\theta,\theta')}{\cos\varphi}$, which must be a function of c. Now t is obviously independent of it; and if we neglect at present the very trifling effect at moderate incidences of the ordinary dispersive powers of the media examined,* φ is so also. It is therefore in the form of the function $\psi(\theta, \theta')$ that we must look for the cause of the phenomena; and since, we have $\theta' = \theta + 2a$, $2a$ being the angle between the axes (because the observations are made in the principal section) we see that $\psi(\theta, \theta + 2a)$ must involve c, and consequently, θ being arbitrary and independent, a must be a function of c. In order then to render the theory of alternations applicable, we must admit the angle between the

* It is easy to see that in the two classes of crystals above described, the effects of the dispersive powers will be opposite to each other, in one opposing, and in the other conspiring with the causes which produce the deviation of tints. In the tables, Nos. V, VI, VII, where the virtual poles were observed almost at a perpendicular incidence, the influence of the dispersive power is quite insensible.

axes of double refraction to differ in the same crystal for the differently coloured rays. We must now show that this supposition is sufficient to represent the phenomena correctly.

The symmetry of the rings and total evanescence of colour in the principal section at an azimuth zero, requires that the axes of all the different colours shall be symmetrically arranged, on either side of a fixed line (which may be called the optic axis) in this plane, or in one perpendicular to it. At present we need only consider the former case. Let a represent the angular distance of the axis for any one standard species of ray C (the extreme red, for instance) from this line, $a + \delta a$, the same distance for any other ray. Then the distance of the transmitted ray C, from the axes of rays of that colour being θ, θ', the corresponding distances from *their* respective axes for rays of any other colour C′ emerging in the same direction will be $\theta - \delta a + \delta\varphi$ and $\theta' + \delta a + \delta\varphi$, $\delta\varphi$ being the difference $(= \varphi' - \varphi)$ of the angles of refraction, corresponding to the same incidence, for the colours C, C′. The positive values of θ here reckon outwards from the pole; δa is negative for crystals of the second class, and $\delta\varphi$ is negative or positive according as C or C′ is the less refrangible colour.

Let us for a moment consider rays of only these two colours. The portion of the extraordinary pencil due to them will be

$$\text{C.}\sin^2\left(\frac{kt}{\cos\varphi}\psi(\theta,\theta').\pi\right) + \text{C}'.\sin^2\left(\frac{k't}{\cos\varphi'}\psi(\theta-\delta a+\delta\varphi,\theta'+\delta a+\delta\varphi).\pi\right).$$

The rays of these colours of the same order in their respective series of rings will therefore coincide, and that in the proper

degree of proportional intensity for the production of a white image, provided we suppose

$$\frac{k}{\cos\varphi}\cdot\psi(\theta,\theta')=\frac{k'}{\cos\varphi'}\cdot\psi(\theta-\delta a+\delta\varphi,\theta'+\delta a+\delta\varphi); \quad (b)$$

which, since $k, k', a, \delta a$, are constant elements, φ, φ' determinate functions of θ, and $\theta'=\theta+2a$, suffices to determine θ.

If we suppose C and C′ to represent the extreme red and violet rays, it is evident that the coincidence of the extraordinary pencils of the same order for these two extremes, will ensure that of the intermediate ones, at least very nearly. It would do so precisely, were the value of δa for any intermediate ray, such a function of k as would result from making θ constant in the preceding equation, because the two laws, that of the dispersion of the axes, and that of the magnitude of the rings of different colours, would then act in exact opposition to each other throughout their whole extent. It is, in fact, a case precisely analogous to that of the compound achromatic prism, where if the law of dispersion in the one medium were identical with that in the other, a perfectly colourless pencil would emerge, and when these laws differ, the coincidence of the red and violet rays ensures an approximate coincidence of all the rest. Should these laws however differ very considerably, an uncorrected colour will appear at the point so determined, and a nearer approximation will be obtained by uniting two of the more powerful intermediate rays, such as for instance the mean red and the blue, or limit of the green and blue.

This then is the origin of the virtual poles or points beyond or between the axes where the tint rises to a white of the first order, more or less feeble, or even to an absolute black; and we may now see the reason why the tints in

reckoning from these points approximate in a general way to the Newtonian scale. In fact, the periods of the more refrangible rays being performed more rapidly than those of the less, if we suppose the coincidence above spoken of to take place at any point (the minimum for instance), of the n^{th} ring, the intervals between the n^{th} and $(n \pm 1)^{th}$ minimum will be greatest for the red and least for the violet, &c. Consequently, when the violet next disappears totally from the extraordinary pencil, there will remain yet a little of the red, less of the orange, and so on, and this difference increasing at every succeeding minimum on either side, will produce a succession of colours approximating in a general way to Newton's scale. This approximation will however be much less close on the side of the virtual pole towards the nearest axis, because the disturbing influence of the separation of the axes on the figure of the rings and the law of their successive intervals, is much more sensible than at a distance from the pole. This will be evident if we consider that in the interval between the extreme coloured axes, the tints will be regulated entirely by the law of their distribution. Now this is perfectly corroborated by the succession of tints in the foregoing tables, as well as by numerous experiments made on other bodies.

Our equation (*b*) gives room for a remark of some consequence, as it affords a striking verification of the theory here delivered. It will be observed that this equation does not involve t, and in consequence, the angle θ determined from it, at which the coincidence takes place, is the same for all values of t, or for all thicknesses of the plate. The observations of the tints in the tables given above, afford us ample

means of putting this remarkable consequence to the test of experiment. In fact, in the three series of tints observed in sulphate of baryta, the apparent angles between the axes for the mean red rays are respectively 62° 0′, 62° 2′, and 61° 53′, the mean of which is 61° 58′, while the apparent angles between the virtual poles in the same series are 72° 46′, 72° 36′, and 72° 47′. The semi-excesses of the latter angles over the mean value of the former, are the apparent angular distances of the virtual poles from the axes of mean red rays, and are respectively 5° 24′, 5° 19′, 5° 25′, neither of which differs more than 4′ from the mean.

To ascertain the real value of θ, we have only to compute the angles of refraction. In the specimen employed, I found 1·6475 for the index of ordinary refraction, and the angles of incidence (the halves of the above angles) being 30° 59′ and 36° 23′, 36° 18′, 36° 24′; the corresponding angles of refraction are 18° 12′ 30″ ($= a$), 21° 6′ 10″, 21° 8′ 40″, 21° 6′ 40″; and since $\theta = \phi - a$ in this case, we find for the values of θ, 2° 53′ 40″, 2° 51′ 10″, 2° 54′ 10″, the mean of which gives 2° 53′ 0″ for the real angular distance of the virtual pole from the axis of mean red rays in sulphate of baryta.

Again, in the series of tints, tables V, VI, VII, for Rochelle salt, the apparent angular distances of the mean red axis from the virtual pole were

277° 8′ − 257° 35′ = 19° 33′; 281° 30′ − 262° 0′ = 19° 30′,
and 282° 0′ − 262° 25′ = 19° 35′

of which neither differs more than 3′ from the mean 19° 33′.

Dr. Brewster (Phil. Trans. 1814, p. 216) has stated the refractive index of this salt at 1·515; but this is certainly a

little too large. In four experiments made at distant intervals of time, and by different modes of observation, I have found

1·49640	1·50220
1·49670	1·49853

for the index for the mean yellow-green rays, of which determinations the last is to be preferred, having been made with great care. The same experiment gave 1·49293 for the index for mean red rays. The apparent angular distance of the axis for red rays from the perpendicular was 16°, which leaves 3° 33′ for the angular distance of the virtual pole from the perpendicular. These angles of incidence correspond to the respective angles of refraction 10° 38′ 20″ and 2° 22′ 40″, of which the sum 13° 1′ is the real angle between the virtual pole and mean red axis in Rochelle salt. The series in table IV, gives 13° 2′ 25″ for the value of θ, which agrees completely with the foregoing determination.

I took seven plates of nitre of various thicknesses, and cut from different crystals, and by a mode of observation to be described hereafter, found as follows:

TABLE VIII.

Designation of the plate.	Mean distance of the virtual poles from the axis of mean yellow rays (apparent.)	Excess above the mean.	Order of the coincidence.
1	1° 50′	— 4′	Between the 4th minimum and 5th maximum.
2	1 51	— 3′	A little beyond the 3d maximum.
3	1 57	+ 3′	Different at the two extremities.
4	1 53	0′	2d maximum.
5	1 55	+ 2′	2d minimum.
6	1 59	+ 5′	9th minimum.
7	1 53	0′	A little beyond the 8th minimum.
	Mean 1 53		

Although the constancy of the position of the virtual pole for different thicknesses is sufficiently made out here, the small differences which exist are certainly not attributable to errors of observation, which, in the method I employed, are usually confined within much narrower limits. They are due to minute irregularities in the crystals themselves, consisting, probably, in a state of imperfect equilibrium of the molecular forces of aggregation, to which this salt is so subject, that it is rather rare to find a specimen in which the rings beyond both poles have exactly the same breadth or tints.

ART. IV. *Of the tints developed by crystals with two axes out of the principal section.*

If we place a crystallized plate at an azimuth zero in a tourmaline apparatus, having the axes of the tourmalines at right angles, we shall observe, if its thickness be at all considerable, that the two oval spots on either side the axis of symmetry (which is now perfectly black) instead of being exactly regular in their figure, as in Fig. 2. Pl. V, and tinged with colours symmetrically disposed on either side of a line *m n* perpendicular to the principal section, are invariably coloured at one extremity *r* with a strong prismatic red hue, and drawn out at the other *v* into more or less elongated and tapering spectra or tails of blue and violet light. The extremities *r*, *r* of the rings too have a large excess of the red rays, and the opposite *v*, *v* of the violet rays. In crystals of the first class above described, the red extremity is turned towards the other pole, while in those of the second it is directed from it. If we subject a plate of Rochelle salt to

this examination, the ovals *a*, *a*, are drawn out to a surprising length, and the whole prismatic spectrum is displayed in them with great vividness of colour, while the violet portions of the rings are greatly elongated also, and appear to run into one another. If the plate be turned round in azimuth, the phenomena assume the most singular appearances of distortion; and as the rotation approaches to 45°, the rings in the vicinity of the pole are gradually obliterated by their mutual overlapping, which is the greater the thicker the plate. In all situations, however, the interposition of a red or dark green glass immediately restores the perfect symmetry and regularity of the rings, which are then seen in much greater number, and completely well defined.

All this is the necessary consequence of the want of coincidence of the axes for different colours. The lateral spots, for example, are formed for each homogeneous colour with perfect regularity close to their corresponding pole, and regularly decreasing in size from the red to the violet. Their arrangement will therefore be as represented in Fig. 3, Pl. V, R, O, Y, &c. being the poles corresponding to the several colours red, orange, &c. The oval spots composed of red rays being represented by *r*, *r*, those of the other colours will be super-imposed on them in their order, overlapping, as represented by the dotted ovals *oo*, *yy*, &c. like the circular coloured images of the sun in the spectrum of an ordinary prism, giving rise to the long prismatic tails above described. Similar considerations will apply to the anomalous appearances presented by the rings of all the other orders and in every situation.

This suggests a very simple and pleasing experiment, which affords an ocular demonstration of the adequacy of the explanation I have advanced. Let a plate of Rochelle salt be placed in a tourmaline apparatus in any azimuth (45° is the most convenient) and firmly fixed on a proper stand in a dark room. The eye being now applied, let an assistant illuminate the emeried glass or lens of short focus* which disperses the light previous to its incidence on the first tourmaline, with the several colours of the prismatic spectrum in succession, beginning with the red. The rings will then be seen formed successively of each of the colours, perfectly regular in their figure, but contracting rapidly in dimension as they become illuminated with the more refrangible rays.† At the same time the pole about which they form will be seen to move regularly in the direction of the other axis of the crystal, and if we pass alternately from a red to a violet illumination, will shift its position accordingly, backwards and forwards through a very considerable angle. If rays of two colours be thrown at once on the apparatus, their two corresponding sets of rings will be seen at once, crossing, but not obliterating one another, and the distance between their respective centres will be observed to increase with the difference of their colours.

By measuring the interval occupied by the projections of

* See the description of an apparatus of this kind, subjoined.

† See Lectiones Opticæ, lib. ii. Pars. i. Obs. xiii. from which the idea of this experiment is taken. "Magnâque voluptate perfusus" says Newton, with the enthusiasm of the true philosopher who loves the field he labours in, "videbam eos dilatare aut contrahere se gradatim pro eo ac color luminis immutabatur." It is impossible to witness the very beautiful phenomenon described in the text without entering into the same train of feeling.

the centres of the last visible red and violet rings, as well as those of the intermediate colours, on a screen at a known distance seen with the other eye, I found the following values of the apparent and real separation of the several coloured axes:

Between	Apparent interval.	Real Interval.
	° ′	° ′
Red and orange	0 37 very uncertain	0 25
Yellow	1 50 rather uncertain	1 13
Green	3 48 Do.	2 29
Blue	6 5	4 3
Indigo	8 19	5 38
Violet	9 46	6 31

As a mode of measurement this method is very inaccurate, especially in the extreme red and violet rays, both of which would be copiously, and indeed almost entirely absorbed in their passage through two plates of tourmaline of a yellowish-green colour. Much more exact and unexceptionable measures will be presently given, but these are quite sufficient to establish the *reality* of the phenomenon described.

V. *Of a secondary cause of the deviation of tints, subsisting in certain crystals, and of the anomalous tints of the apophyllite.*

To determine the dispersive power of any medium, and obtain some rough knowledge of its law, we make a prism of it act in opposition to one of a standard substance. To ascertain the total dispersion of the axes of a crystal, or the angle by which the extreme red and violet axes differ, we may make it act against itself. Since the violet rings are more elevated by refraction than the red, from the situation in which they

would appear to an eye immersed in the medium, a plate may be conceived cut in such a direction as to make their apparent centres coincide, in which case the tints immediately about the poles will coincide with NEWTON's scale, and the extraordinary image will totally disappear in the pole at an azimuth 45°. This condition gives $\theta = 0$, $\theta - \delta a + \delta\varphi = 0$, whence (supposing R, R′ the indices of refraction for extreme red and violet rays and $\delta R = R' - R$) we find

$$\delta a = \delta\varphi = -\frac{\delta R}{R} \cdot \tan\varphi$$

The angle φ however becomes imaginary, and this method, in consequence, inapplicable when the separation of the extreme axes (δa) is greater than the maximum dispersion of the colours of an intromitted white ray, that is, when

$$\delta a > \frac{\delta R}{R.\sqrt{R^2-1}}$$

Let us resume our equation *(b)*, and supposing the form of the function ψ, and the constants a, k, k', R and δR ascertained, let the angle θ, at which the coincidence takes place be observed, and the value of δa will then become known. If we suppose it small, which it is in the generality of crystals, we get

$$\delta a = \frac{\frac{k-k'}{k'} \cdot \psi - \delta\varphi \cdot \left\{ \frac{k}{k'} \cdot \sin\varphi \cdot \psi + \frac{d\psi}{d\theta'} + \frac{d\psi}{d\theta} \right\}}{\frac{d\psi}{d\theta'} - \frac{d\psi}{d\theta}}; \qquad (c)$$

(ψ being put for $\psi(\theta, \theta')$ for the sake of brevity). At incidences nearly perpendicular, $\delta\varphi$ may be neglected, and the expression reduces itself to

$$\delta a = \frac{k-k'}{k'} \cdot \frac{\psi}{\frac{d\psi}{d\theta'} - \frac{d\psi}{d\theta}} \qquad (d)$$

The comparison of these formulæ with observation, which

will lead to some very remarkable consequences, requires us to know the form of the function ψ and the values of k, k'. We will begin with the former, and in this investigation the first step is to determine the general equation of the isochromatic lines. In order to this, we must separate in all cases the law of the tint from that of its intensity. The latter depends entirely on the greater or less facility which the emergent ray finds in penetrating the prism of Iceland spar employed for its analysis, and will not enter into the present investigation. When we examine a crystallized plate in a convenient graduated apparatus, between tourmaline plates crossed at right angles, turning it slowly round between them in its own plane, the form of the coloured bands, if illuminated with homogeneous light, will remain perfectly unchanged during the rotation, but the two black hyperbolic branches passing through the poles, will obliterate in succession every part of their periphery; and the space over which the darkness extends, as well as the degree of illumination of what remains visible, varying at every instant, give rise to so great a variety of appearances, that some little attention is required to recognize this perfect identity of figure. When the tourmaline next the eye is made to revolve, the crystallized plate remaining fixed, the complicated changes which take place, are perfectly reconcilable with the superposition of the primary on its complementary set of rings, the relative intensities of the two sets at any point being regulated by laws we have no occasion to consider at present, but the figure of the isochromatic lines, where visible, remains absolutely unchanged by any rotation in this part of the apparatus.

To form a first hypothesis on the nature of the function

which determines the equation of any one of these curves, we must select a crystal, where the proximity of the axes and intensity of the polarising forces are such, as to bring the whole system of rings within a very small angular compass; as by this means we avoid almost entirely the disturbing effect of the variation in thickness, arising from obliquity of incidence. Dr. BREWSTER, in his Paper of 1818, has chosen nitre, as affording the best general view of the phenomena, and it is admirably adapted for this purpose; the whole system of rings being comprised at a very moderate thickness within a space of 10°, allowing us to regard their projection on a plane perpendicular to the optic axis as a true representation of their figure, undistorted by refraction at the surface, &c. If we examine the rings in this crystal (illuminated with homogeneous light, or by the intervention of a red glass in common day-light) it will be evident that the general form of any one of them is a re-entering symmetrical oval, which no straight line can cut in more than four points, and which, by a variation of some constant parameter, is in one state wholly concave, as 1 (Fig. 4. Plate V.) then becomes flattened, as 2; then acquires a minimum ordinate and points of contrary flexure, as 3; then a node, as 4; after which it separates into two conjugate ovals, as 5; which ultimately contract themselves into the poles P, P′ as conjugate points. The general idea bears a striking resemblance to the variation in form of the curve of the fourth order, so well known to geometers under the name of the lemniscate, whose equation is

$$(x^2+y^2+a^2)^2 = a^2\,(b^2+4\,x^2)$$

when the parameter b gradually diminishes from infinity to

zero, $2a$ being the constant distance between the poles. In order, however, to put this to a satisfactory examination, accurate measures must be taken, which, in the case of nitre, from the minuteness of the system of rings, presented at first some difficulties. These I obviated, after many fruitless trials, by a mode of observation which I have found extremely convenient and accurate, and which applies particularly well to the present purpose. It consists in projecting the rings by solar light on a screen in a darkened room, by which means they may be magnified to any required extent, examined at perfect leisure, and in all their phases, and measured or traced with a pencil with the utmost exactness and facility. They may be thus exhibited too to a number of spectators at once; a thing which may prove serviceable to the Lecturer, for which reason I have subjoined to this paper a brief description of the apparatus I employ.

Having cut a very perfect crystal of nitre at right angles to its axis of crystallization, and adjusted it properly on this apparatus, the rings were projected on a large sheet of paper, stretched, while moist, on a drawing board, by which means it assumes a truly plane surface by the contraction it undergoes while drying. The poles were then marked, and the loci of the successive maxima for red rays carefully outlined. The screen being then removed, a series of lemniscates were laid down by points, having the same poles and one common point in each, chosen where the tint was most decided. It is unnecessary to give any comparative statement of measures in the observed and constructed curves, as the points, graphically laid down, uniformly fell on the pencilled outlines, or, in the few instances to the contrary,

within limits less than the very trifling irregularities of the outlines themselves.

The graphical construction of these curves is rendered extremely easy by the elegant and well-known property of the lemniscate, in which the rectangle under two lines drawn from the foci (or poles) to any point in the periphery, is invariable throughout the whole extent of the curve. This is easily shown from its equation, and the value of this constant rectangle in any one curve is expressed by $a\,b$.

We must next enquire how the constant parameter b varies in passing from ring to ring. To this end I projected the rings, illuminated by red light only, on a screen as before, and having outlined the successive loci of the minima of illumination, and laid down the poles, found the values of $a\,b$ in the several lemniscates, as in the following table:

Order of the minimum.	Observed values of $a\,b$ in square inches.	Differences.	Values of $a\,b$ computed from formula $a\,b = 1{\cdot}59 \times n$	Excess of computed above observed values of $a\,b$
$n = 0$	0·00		0·00	0·00
1	1·62	1·62	1·59	− 0·03
2	3·165	1·545	3·18	+ 0·02
3	4·69	1·525	4·77	+ 0·08
4	6·27	1·58	6·36	+ 0·09
5	7·87	1·60	7·95	+ 0·08
6	9·56	1·69	9·54	− 0·02
7	11·09	1·53	11·13	+ 0·04
8	12·77	1·68	12·72	− 0·05
9	14·33	1·56	14·31	− 0·02
10	15·93	1·60	15·90	− 0·03
		Mean 1·59		

The nature of the illumination not allowing the delineation to be performed with the same freedom and precision as in a fuller light, the values of $a\,b$ in the second column are the means of a great number of measures, taken in every part

of their respective curves. The numbers in the 5th column exhibit the excesses of the terms of the arithmetical progression in the 4th (whose common difference is 1·59, the mean of all the differences in the third column) above the observed values of $a\,b$, and are so small as fully to authorize the conclusion, that these values, and of course those of the parameter b, increase in arithmetical progression with the order of the rings; or in other words, that the number of periods performed in a given space (=1) by a luminous molecule going to form any point M in the projection of any ring, is proportional to the rectangle of the distances P M, P′ M of that point from the two poles.

Now, if we extend our views to crystals in which the distance between the axes is considerable, we may reasonably expect that the usual transition which takes place in analytical formulæ from the arc to its sine, when we pass from a plane to a spherical surface, will hold good. If this be the case, we shall have at once, and in all cases

$$\psi(\theta, \theta') = \sin\theta . \sin\theta'$$

and the nature of the isochromatic curve for the n^{th} complete period will be expressed by the equation

$$\sin\theta . \sin\theta' = \frac{n}{kt} \cdot \cos\varphi = n\,h . \cos\varphi \qquad (e)$$

putting h for $\frac{1}{kt}$. If the plate be cut at right angles to the optic axis

$$\cos\varphi = \frac{\cos\theta + \cos\theta'}{2 . \cos\alpha}$$

and consequently

$$\sin\theta . \sin\theta' = \frac{n}{2\,k\,t . \cos\alpha}(\cos\theta + \cos\theta') ; \qquad (f)$$

To put this to the trial, I took a plate of mica, whose thickness measured 0·023078 inch, and having adjusted it accurately on a divided apparatus, placed it in an azimuth 45°,

and, by the intervention of the red glass above mentioned, observed the maxima and minima of the extraordinary pencil between the poles. As these observations, when repeated, seldom agreed unless within a few minutes, ten were taken of each maximum and minimum. The angles of incidence, deduced from a mean of similar observations on each side of the perpendicular, are set down in the 2d column of the following table, each number in which is therefore a mean result of 20 observations. The 1st column contains the values of n, or the order of the ring observed; the 3d, the angles of refraction, to obtain which I used the index 1·500, employed by M. Biot.* The 4th and 5th columns contain the values of θ, θ' thence computed, and the 6th, values of the coefficient h, deduced from the formula $h = \frac{\sin\theta \cdot \sin\theta'}{n \cdot \cos\varphi}$ in.

TABLE X. *Mica. Thickness*=0·023078.

Values of n	Angles of Incidence.	Angles of Refraction.	Values of θ.	Values of θ'	Values of h.	Excesses above mean.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″		
0	35 3 30	22 31 0	0 0 0	45 2 0		
0·5	32 55 20	21 14 40	1 16 20	43 45 40	0·033052	— 0·000195
1	30 34 40	19 49 30	2 41 30	42 20 30	0·033622	+ 0·000475
1·5	28 15 40	18 24 0	4 7 0	40 55 0	0·033035	— 0·000112
2	25 34 20	16 43 30	5 47 30	39 14 30	0·033327	+ 0·000180
2·5	22 46 20	14 57 15	7 33 45	37 28 15	0·033148	+ 0·000001
3	19 35 40	12 55 10	9 35 50	35 26 10	0·033058	— 0·000089
3·5	15 48 40	10 27 50	12 3 10	32 58 50	0·033026	— 0·000121
4	10 48 50	7 11 10	15 19 50	29 42 10	0·033010	— 0·000137
					0·033147	

* Recherches sur les Mouvemens des Molecules de la lumiere, &c. p. 482. He takes it equal to that of glass—"ce qui ne doit pas etre fort éloigné de la verité." I have attempted, without success, to measure its value. What has satisfied M. Biot and Dr. Brewster (for the latter has evidently used this index, or one very near it, Phil. Trans. 1818, p. 230) ought to satisfy every one: yet it is fortunate that in the present instance, a slight variation in the refractive index will produce but a very trifling change in the *relative* values of b.

The last column of this table exhibits the deviations in excess or defect of the values of the quantity h, so computed from the mean of all of them. Their smallness, in comparison with the quantity itself, and their alternations of sign, are evident proofs of the constancy of this coefficient, and we are therefore authorized to take $\sin\theta \times \sin\theta'$ as the general value of $\psi(\theta, \theta')$. The observations on Rochelle salt, presently to be noticed, confirm this law.* If we denote by l the minimum length of a double oscillation, or the space passed over during one complete period by a ray transmitted at right angles to both axes, we have $k = \frac{t}{T}$; and consequently $h = \frac{l}{t}$, $l = h\,t$. If we substitute for h and t their values above found, we obtain

$$l = 0{\cdot}00076497 \text{ inch}$$

for the minimum length of a period performed by a mean red ray in mica.

* When $\theta = \theta'$, as in crystals with one axis, we have $\psi(\theta, \theta') = \sin^2\theta$, a result long since confirmed by the accurate experiments of Brewster and Biot. The velocity of the extraordinary ray in such crystals is given by the formula $v^2 = V^2 + \alpha \cdot \sin^2\theta'$. Following this analogy, we may conclude that in crystals with two axes we should have $v^2 = V^2 + \alpha \cdot \sin\theta \cdot \sin\theta'$. Now this is precisely the expression at which M. Biot has recently arrived. This very simple and elegant result was communicated to me by that eminent philosopher in the spring of this year, and subsequently in a letter of the 2d May. His Memoir on the subject, which appears (by the Ann. de Chim.) to have been read to the Institute in April, I have not seen, nor do I know by what precise steps he was led to it, but presume it must have been by some considerations of the nature above described. In the foregoing investigation of the law of periodicity, I beg leave therefore to disclaim all intention of arrogating to myself any share in this beautiful discovery, but have thought it necessary to state the steps in the text, in order to demonstrate a truth essential to the investigations to follow, which could not have been taken for granted, or deduced by any legitimate reasoning, independent of experiment, from the equation $v^2 = V^2 + \alpha \cdot \sin\theta \cdot \sin\theta'$, by reason of our ignorance of the nature and mode of action of the polarising forces; and, have purposely abstained from entering any farther into the general laws of double refraction and polarisation than I could possibly avoid.

Resuming our general equations *(b)* and *(d)* if we substitute the value now determined for ψ, and write $\frac{l}{\rho}$ for $\frac{k'}{k}$, we have

$$l' . \cos\varphi' . \sin\theta . \sin\theta' = l . \cos\varphi . \sin(\theta - \delta a + \delta\varphi) .$$
$$\sin(\theta' + \delta a + \delta\varphi) ; \qquad (g)$$

whence it is easy to derive (independent of any approximation)

$$\cos 2(a + \delta a) = \cos 2\varphi' + 2\frac{l'}{l} \cdot \frac{\cos\varphi'}{\cos\varphi} \cdot \sin\theta . \sin\theta' ; \qquad (h)$$

while our approximate equation *(d)* furnishes the following very convenient formula for incidences nearly perpendicular

$$\sin\delta a = \frac{l - l'}{l} \cdot \frac{\sin\theta . \sin\theta'}{\sin 2a} . \qquad (i)$$

The simplest supposition we can frame relative to the values of the constant elements l, l' is their proportionality to those of c, c', or the lengths of the fits of easy reflection and transmission. This cannot certainly be far from the truth in crystals with one axis, in which the coincidence of the tints, with those of NEWTON's scale, is for the most part exact. In sulphate of lime too, and mica, the only crystals with two axes which have been examined with sufficient exactness, and under the proper circumstances for ascertaining this important point, the law of proportionality seems to be sustained with great precision. This may seem to authorize the general conclusion, that in all cases, $\frac{c}{c'} = \frac{l}{l'}$. Let us see how this agrees with the measures given in the former part of this paper.

In sulphate of baryta, if we take Dr. BREWSTER's measure of the dispersive power,* we have $\delta R = 0{\cdot}019$, and consequently, calculating on the data determined in page 71, we must have, at the virtual pole,

$$\varphi = 21^\circ 5' 30'' \qquad \varphi' = 20^\circ 50' 30'' \qquad \delta\varphi = -15'$$

Now, if we suppose $l = 6{\cdot}3463$ $l' = 3{\cdot}9982$, the values of c

* $\delta R = 0{\cdot}019$. Treatise on new Philosophical Instruments.

and c' respectively for the extreme red and violet rays,* we shall find by substitution in our formula (*h*)

$$\delta a = 51' 10''$$

But a red ray penetrating the surface from within the crystal at an angle $a = 18°12' 30''$, and a violet one at an angle $a + \delta a = 19° 3' 40''$, would emerge at the respective angles 30°59′ and 32°58′ 20″, and would include between them an angle of 1°59′ 20″, which should be the *apparent* separation of the red and violet axes in the plate employed. Now, previous to the computation of this result, I had carefully measured this angle, by observing the incidences at which the extreme red and violet rays of the prismatic spectrum, received on the reflector of a graduated apparatus, respectively disappeared from the extraordinary image at the poles P, P′. I thus found

Interval of the poles P, P′ for red rays - 62° 2′
Do. for violet - - 66° 5′

Semi-difference, or apparent separation of the axes 2° 1′ 30″ which differs from its computed value only by 2′ 10″. We may therefore fairly conclude, that in the case of sulphate of baryta, the hypothesis $\frac{l}{l'} = \frac{c}{c'}$ does not deviate sensibly from the truth.

If we apply our formula (*i*) to the measures above given for Rochelle salt, the result will be widely different. The same supposition as to the values of l, l' being made, we get

$$\delta a = 4° 2' 50''$$

The incidence being nearly perpendicular, and the angle small, we need only increase it in the proportion 1·499 : 1, to have the apparent angle, which thus comes out 6° 4′. We have already found 9° 46′ for the same angle, by a method which

* Biot, Traité de Physique. Vol. IV.

must necessarily give a result much below the truth. This difference is by far too great to arise from any errors of observation; but to obtain more exact measures, I took several times the apparent angular separation of the axis of each colour from that of the extreme red by the direct homogeneous light of a sunbeam, separated by the prism, and received on the reflector of a divided apparatus, when, after the proper reductions for refraction and dispersion, the results were as follow:

Colour.	Apparent separation of the axes.	Real separation = 2 a m	Values of 2 a.	Number of observations.
	° ′	° ′	° ′	
Extreme Red.	0 0		75 42	13
Mean Red.	1 33	1 2	73 38	45
Do. Orange.	2 37	1 44	72 14	18
Do. Yellow.	4 0	2 40	70 23	20
Green.	5 49	3 52	67 57	16
Blue.	8 2	5 27	65 0	13
Indigo.	10 21	6 54	61 54	33
Indigo Violet.	11 17	7 31	60 40	2
Mean Violet.	13 58	9 17	57 8	2
Extreme Violet.	15 23	10 14	55 14	8

Though the total separation of the red and violet axes in this table so far exceeds what we had before estimated it at, I am fully satisfied that it is no way exaggerated, but rather falls short of the truth. It is very practicable, by combinations of coloured glasses, liquids, &c. to insulate either extremity of the spectrum in a state of the most absolute purity. In this climate, the dispersed light of the sky in the neighbourhood of the sun, which always mixes with the prismatic beam, is so considerable as to obliterate the feeble rays which compose the two extremities of the spectrum, and it is only by interposing such combinations between the eye and the Iceland crystal used to analyze the polarised ray, that they

can be examined with any certainty. The combination I employed for the extreme red was such, that when the whole spectrum thrown on a white screen was viewed through it, it was seen reduced to a perfectly circular, well defined, deep red image, whose *centre* fell on the very farthest *termination* of the red as seen by the naked eye, and whose circumference attained, or perhaps surpassed the point where the maximum of the calorific rays has been supposed to be situated. In like manner, when the same spectrum was examined with the violet combination, a very slightly elongated violet image became perceptible, but every trace of the indigo, and the brighter portion of the violet rays was extinguished. For observations on the indigo, and all the more refrangible portion, I employed similar artifices, without which I found it perfectly impracticable to obtain any regular and comparable results.

The coefficient $\frac{l-l'}{l}$ in our formula being the only part not immediately deduced from observation, it is evident that the assumption $\frac{l}{l'}=\frac{c}{c'}$ must be widely erroneous in the present instance, and it therefore becomes necessary to ascertain the values of l by direct measures. This is rendered easy by the equation (e) which gives

$$l=t.\frac{\sin\theta.\sin\theta'}{n.\cos\varphi}.$$

We have only therefore to observe the inclinations of a plate of known thickness, properly cut and adjusted to 45° azimuth, which correspond to the alternate disappearances of the ordinary and extraordinary images, at which points the values of n are $\frac{1}{1}, \frac{3}{2}, \frac{5}{3}, \frac{7}{4}$, &c; computing then the values of θ, θ', and φ, and substituting, we get the values of l, without

detailing particular experiments. The following table expresses the final result of a great number of such measures.

Colour.	Values of l in inches.	Number of Observations.
Extreme Red.	0·0056158	64
Mean Red.	0·0050033	14
Mean Orange.	0·0045852	24
Mean Yellow.	0·0040583	52
Mean Green.	0·0036549	62
Mean Blue.	0·0032863	22
Mean Indigo.	0·0029868	52
Extreme Violet.	0·0025093	49

The observations from which this table was calculated, were made indiscriminately on the maxima and minima of all orders. Those of different orders were of course computed separately, and found to agree without exception in giving the same values of l within limits of error less than those to which the observations are liable; thus affording another proof of the exactness of the law of periodicity above employed. Now, if we compare these, one with another, and with those of c as deduced by M. Biot from Newton's observations, we shall have as follows:

Colour.	Values of $\frac{l}{l}$	Values of $\frac{c}{c}$
Extreme Red.	1·00000	1·00000
Mean Red.	0·89093	0·96215
Mean Orange.	0·81659	0·90490
Mean Yellow.	0·72266	0·85550
Mean Green.	0·65082	0·79433
Mean Blue.	0·58520	0·73725
Mean Indigo.	0·53156	0·69641
Extreme Violet.	0·44684	0·63000

It appears from this comparative statement, that the forces of polarisation and double refraction in the body now examined, act with much greater proportional energy on the more refrangible rays than in mica, sulphate of lime, and

other similar bodies, and consequently that, even were its axes coincident, its tints, though perfectly regular, would still differ very sensibly from the colours of thin plates. This secondary cause of deviation ought to become sensible in plates cut so as to contain both axes, if examined at a perpendicular incidence; but I have not yet had an opportunity of making the trial.

If we calculate on the numbers above given, it will soon appear that a perfect coincidence of all the colours in a single virtual pole is impossible. For this purpose we may employ our equation (*i*) which easily affords the following

$$\cos 2(a+\theta) = \cos 2a \left\{1 + \frac{2l}{l-l'} \cdot \tan 2a \cdot \sin(-\delta a)\right\}$$

$$= \frac{\cos 2a}{(\cos M)^2}$$

taking M an auxiliary angle such that

$$\tan M = \sqrt{2} \cdot \tan 2a \cdot \frac{l}{l-l'} \cdot \sin(-\delta a)$$

whence the value of θ or the position of the coincidence of any two coloured rays becomes known, the values of l, l', and $-\delta a$ being given from the foregoing tables. If we unite the mean red with the mean green, these formulæ give $\theta = -11^\circ 29'$, and if with the mean blue, $\theta = -14^\circ 8'$, of which the one falls short of, and the other exceeds the angle $-13^\circ 1'$ given by observation. If we determine by interpolation the values of l' and $-\delta a$, which give $\theta = -13^\circ 1'$, we shall find very nearly

$l' = 34581$ $\quad -\delta a = 3^\circ 37'$ $\quad -\delta a + 1^\circ 2' = 4^\circ 39'$

which correspond to a blue ray strongly inclining to green, and in the brightest part of the colour. Now it is evident that when a rigorous union of all the rays in the proportion in which they exist in white light, is impossible, that of the

strongest and brightest colours in opposition to each other will at least ensure the nearest approach to a virtual pole on the principles above demonstrated, and a white will thus be produced, not indeed mathematically perfect, but containing no marked excess of any of the more powerful colours.

The apophyllite is the only crystal with one axis whose tints exhibit a sensible deviation from the scale of NEWTON. Its phenomena, however, are entirely independent of the first and principal cause which produces the deviation in crystals with two axes, viz. the separation of the axes of differently coloured rays, and are referable solely to the secondary and subordinate cause, of which Rochelle salt has just afforded an example, viz. a peculiarity in the law which regulates the lengths of the minimum oscillations of the differently coloured rays within the medium.

1. The tints of the apophyllite commence at the centre of the rings and increase in regular progression outwards, following the same order, whatever be the thickness of the plate.

It follows from this, that the multiplier M in our general formula, (a) is the same for all the coloured rays, being zero at the commencement of the scale; and hence it follows, as a necessary consequence, that the axes of all the colours are united in one, and the virtual and actual poles coincide with each other and with the centre. Did any sensible separation of the axes exist, it must become perceptible by the ellipticity of the rings when examined with homogeneous light of that colour from which they are farthest asunder; but with the greatest attention, in plates of considerable thickness, I have not been able to observe the slightest shifting of the axis, or deviation from the circular figure, in passing from a red to a

violet illumination. Moreover, it is evident from the preceding theory, that any difference which may exist in their position, if too small to be sensible to the eye, can produce only an imperceptible deviation of tints. In fact, if we suppose $a = o$ for any colour, we get, for the position of the virtual pole,

$$\sin\theta = \sqrt{\frac{l-l'}{l}} \cdot \sin\delta a$$

θ being the angular distance of the point of coincidence from the single axis of that colour. It is, consequently, insensible when δa is so. Now, the polarising force of the apophyllite being very feeble, the diameters of the rings in any plate of moderate thickness must so far exceed this very minute quantity, that the virtual poles, did any exist, must fall within the limit of the central blackness; the Newtonian scale would still appear to commence from the centre, nor could any sensible deviation from it arise from this cause.

2. When the prismatic spectrum is passed over an apparatus containing a plate of this mineral, no perceptible change in the *magnitudes* of the rings for different colours takes place. Hence it appears that the value of the function l for all the coloured rays is nearly alike. By measures taken on a divided apparatus, a slight difference is observed. Taking the mean refractive index R at 1·5481 (by a very careful measure) and the dispersion δR at 0·017, the formula

$$l = t \cdot \frac{\sin^2\theta}{n \cdot \cos\phi} = \frac{t}{n} \cdot \sin\theta \cdot \tan\theta$$

gave as follows:

Extreme Red.	l = 0·0093066
Mean Red.	0·0092810
Mean Orange.	0·0092337
Mean Yellow.	0·0091503
Mean Green.	0·0090643
Mean Blue.	0·0092059
Mean Indigo.	0·0093964
Extreme Violet.	0·0100660 ?

This table, though not given as exact, owing to imperfections in the specimen examined, agrees with the succession of tints which, as far as the fourth order, were as follows:

Apophyllite. *Thickness* = 0·0829 in.

Incidence.	Ordinary pencil.	Extraordinary.	
° ′			
0 0	Bright white	Black	The axis.
13 50	White with a trace of purple	White slightly greenish	1st. maximum of illumination.
21 50	Exceeding sombre violet	Pure bright white	
25 12	Pale greenish yellow	Purplish white	
29 45	White	Sombre violet blue	
30 50	White	Extremely sombre violet	1st. minimum.
33 3	White with a strong tinge of violet	Pale yellow green	
35 50	Blue strongly inclining to purple	Greenish white	
37 20	Sombre indigo inclining to violet	White	
38 5	Sombre violet	White	2d. maximum.
40 10	Tolerably good yellow green	Purplish white	
43 55	White with a trace of yellow	Obscure indigo inclining to purple.	
44 27	White	Sombre violet	2d. minimum.
46 45	Pale purple	Tolerable yellow green	
49 57	Sombre purple blue	Yellowish white	
50 30	Sombre violet	White	3d. maximum.
53 40	Green yellow	Pale purple	
56 0	Yellowish white	Sombre indigo blue	3d. minimum.
56 40	Yellowish white	Sombre violet	
	White	Livid grey	
59 35	Pale purple	Yellow green	
61 45	Sombre indigo	Pale yellowish white	4th. maximum.
62 10	Sombre violet	Yellowish white	
63 0	Faint violet white	White	
	Livid grey	White	
66 0	Tolerable green yellow	Purple	
69 30	Yellow white	Very sombre indigo	4th minimum.

In the colours of thin plates and others of the like composition, the difference in the lengths of the periods of the different rays is so considerable, that after seven or eight alternations of colour the rings confound one another, and are blended into a uniform whiteness. Were the periods more nearly equal, a greater number of rings should be visible, and were they strictly so, the succession of alternate whiteness and blackness should be continued to infinity. As the values of

l, l'', &c. in the apophyllite approximate pretty closely to this limit, we should expect to see a much greater number of rings, and this I find to be really the case. By enclosing a thick plate in balsam of copaiba in a proper apparatus to increase the range of incidence, I have counted as far as the 35th order, when I desisted; not from any want of alternate colours, but owing to their extreme closeness, which rendered it impossible to number them distinctly. Indeed I have no doubt, that could a very thick and limpid specimen be procured, hundreds might be seen without artificial aid.

In two instances then, at least, and probably in many more, or perhaps to a certain small degree in all cases, the minimum lengths of the periods deviate in their respective proportions from those of the fits of easy transmission and reflection; a circumstance which of itself is sufficient to prove the independence of the causes of these laws of periodicity. If we take R r = R A, Fig. 5, Pl. V. and construct a curve whose abscissas A P are the values of c, c', &c. and ordinates those of l, l', &c. the straight line $r\,o\,y\,g\,b\,i\,v$ inclined at 45° to A R will represent the locus for crystals, such as carbonate of lime, in which the periods follow the Newtonian law, $r'o'y'g'b'i'v'$ will represent the same locus for tartrate of soda and potash, while $r''o''y''g''b''i''v''$ is the curve similarly traced for apophyllite.*

* Having communicated to Dr. Brewster my observations on the deviation of tints, and the conclusion I had thence deduced as to the separation of the axes of the differently coloured rays, I received in answer a letter, from which, in justice to that indefatigable observer, I subjoin the following extracts.

"My Dear Sir, *Esk Hill, by Roslin Lasswade, Sept.* 18, 1819.

"In consequence of having been some time from home, I have only now received your letter, and hasten to reply to that part of it in which you request me to state

what results I had obtained respecting the deviation of the tints from NEWTON's scale. The following general points will enable you to judge of the progress which I had made in the enquiry.

" 1. In almost all crystals with two axes there is a deviation from the tints of NEWTON's scale.

" 2. This deviation is greater in some crystals than in others, being a maximum in acetate of lead and tartrate of potash and soda.

" 3. That all these crystals may be divided into two classes, viz. those which have the *red* ends of the rings inwards and the blue ends outwards, and those which have the red ends outwards and the blue ends inwards.

" 4. That in all crystals with two axes, the doubly refracting force of *one axis* in general acts differently upon the differently coloured rays from the doubly refracting force of the *second* axis.

" 5. That as the polarising force is always proportional to the force of double refraction, the polarising force of one axis will act differently on the differently coloured rays from the polarising force of the other axis.

" 6. . . . . .

" 7. The consequence of this is, that there will be different resultant axes, or different points of compensation for the differently coloured rays.

" 8. All these effects may be calculated with the utmost accuracy, if the ratio of the dispersive powers of the two extraordinary refractive forces is given, or *vice versâ*, the dispersive powers may be obtained from the angles of the resultant axes for the red and violet rays of the spectrum.

" 9. I have found crystals in which these phenomena *are decidedly connected* with the rotatory phenomena; and from this highly important fact I am led to conclude, that both have the same origin, and that all the rotatory phenomena are, as I have stated in my paper, the result of the uncompensated tints of two axes, equal *for the mean ray*, but unequal for all the rest. (*Here follows an illustration by a diaphragm.*)

" 10. The division into two classes in § iii. as founded merely on observation, is converted into another division into two classes, viz. 1. That in which the doubly refracting force of the principal axis acts more powerfully on the blue rays than the other axis does; and 2. That in which it acts less powerfully. The first class comprehends those crystals in which the blue ends are inwards, and the second those in which the red ends are inwards, or nearer the principal axis."

In a subsequent letter (Oct. 4), he adds,

" The *virtual poles*, which you mention, I discovered in the year 1815, and I have two accounts of them in my Journal, the one signed on the 24th January, 1816, and

the other 6th January, 1817, by Sir G. MACKENZIE, President of the Physical Class of the Royal Society."

No comments on the above extracts are necessary. They establish at once the priority of Dr. BREWSTER's observations, and the independence of mine. With regard to the division of crystals into two classes, which observation has alike suggested to both of us, it is unnecessary, if we regard either of the two classes as having the angle between the resultant axes greater than a right angle. In Dr. BREWSTER's table, Phil. Trans. 1818, p. 230, succinic acid and sulphate of iron are stated as having this angle 90°. If this determination corresponds, as in all probability it does, to the yellow rays, they belong at once to both classes, and are, in fact, instances of the limit where one class passes into the other. Bi-carbonate of ammonia, in which I can perceive no separation of the axes of different colours, nor of course, any virtual poles, belongs in like manner to both classes, or to neither.

JOHN F. W. HERSCHEL.

APPENDIX.

Description of an instrument employed in the foregoing experiments on the polarised rings.

The singular property possessed by the tourmaline, by which a plate of it of any moderate thickness cut in a direction parallel to its axis of double refraction, is enabled to absorb the whole, or nearly the whole, of an incident pencil polarised in a plane parallel to that axis,* was pointed out by

* The same property is observable in the epidote, the axinite, and all other natural and artificial crystals which exhibit any degree of dichroism when examined by *unpolarised* light. Muriate of palladium and potash possesses it in the highest perfection. This remarkable effect is easily explained by a reference to the general principles laid down by Dr. BREWSTER in his paper on absorption, Phil. Trans. 1819, p. 11. The incident pencil is separated by the doubly refractive force into two, oppositely polarised, one of which is partly absorbed, the other emerges (polarised in its proper plane) of nearly its original intensity.

M. Biot, in the fourth vol. of his Traité de Physique, and he has availed himself of it with his accustomed ingenuity, as affording an extremely ready and convenient mode of viewing the phenomena of polarisation, much more so than by the use of plates of agate, prisms of Iceland spar, or a second reflection. It follows, from the above mentioned property, that if a beam of ordinary light be made to traverse such a plate, the whole of the emergent pencil, or nearly so, will be polarised in a plane at right angles to the axis; for the incident ray being divided by the doubly refracting force into two pencils, polarised in planes, the one parallel, the other perpendicular to the axis, the former is extinguished in its passage, while the latter emerges with nearly its full intensity.

Hence, if two such plates are crossed at right angles, though separately very transparent, their combination will be opaque. There is a great difference, however, in the degree in which tourmalines of different colours possess this power. Those of a light green, pink, or bluish colour, are quite improper, allowing a considerable portion of light to pass when so crossed, while, on the other hand, those whose colour verges strongly to the honey yellow, or to the hair brown, or purplish brown, effect nearly a complete absorption, and afford, when crossed, a combination almost impervious to light. In ignorance of this distinction, I sacrificed several fine and valuable specimens before I could obtain proper plates.

When a crystallized lamina, cut in a proper direction, is interposed between such a combination of plates, it disturbs the polarisation which the light has received in traversing the first plate, and renders a certain portion of it capable of

traversing the second: the colour and intensity of this portion varying with the direction of the ray, give rise to the phenomena of the polarised rings, which may accordingly be seen by applying the eye, and receiving on it the dispersed light of the clouds, &c.

In order, however, to equalize as well as disperse the light, which is of great importance to obtaining a perfect view of the phenomena, an emeried glass may be cemented on the anterior plate, or the first surface of the plate itself roughened; but it will be found more convenient in practice to employ a double convex lens of short focus for this purpose, by which, if necessary, a very strong illumination may be obtained, and an extremely minute portion of a crystal subjected to examination. I have thus, occasionally, examined the rings in a portion not exceeding the hundredth of an inch in diameter, and thus detected irregularities of crystallization of a very singular nature, in many bodies, which would have eluded any other mode of observation. For this purpose, the crystal must be cemented over a small aperture in a thin sheet of brass, on which the focus of the lens must be exactly adjusted to fall.*

If, instead of applying the eye to receive the light so dispersed, we place a screen at some distance in a darkened room, the apparatus is converted into a solar microscope, and the rings will be seen projected on the screen. The con-

* I have now an apparatus preparing, in which the first plate of tourmaline itself is formed into a double convex lens, by which the loss of light at two surfaces will be suppressed. It is easy to adapt such a lens to a double microscope, for the purpose of detecting microscopic irregularities; and I have reason to suppose a variety of curious results will be brought to light by these means.

struction of the apparatus I employed is as follows. AB is a brass tube, within which are fitted, 1st, a fixed diaphragm, *a a b b*, carrying the first plate of tourmaline in its centre; 2dly, a diaphragm, *c c d d*, moveable freely in its own plane by means of the pin *g* passing through a slit in the side of the cylinder A B, which occupies an arc of about 120° of its circumference. This is destined to receive the crystallized plate *d d*, while a cylinder, *h h e e f f*, made to slide and turn smoothly within A B, carries the second tourmaline, *f f*. It is essential that the tourmalines employed for this purpose, and especially the posterior one, should be perfectly free from all flaws and blemishes; but large plates not being required, this condition is easily satisfied. The plates so arranged, and brought as near together as possible, the extremity A, of the cylinder A B, is fitted to slide somewhat stiffly on the brass tube P Q, furnished with a lens L, of about two inches focus, and a screw P P, by which it can be adapted to the apparatus usually employed for reflecting a sunbeam into a darkened chamber. The sliding motion of the cylinder A B allows the focus of the lens to be adjusted so as to fall exactly on the first surface of the posterior tourmaline *f*, while its rotation suffers the axis of the anterior one to be placed perpendicular to the plane of reflection. By this arrangement two advantages are gained. The reflector employed (though metallic) always polarises a more or less considerable portion of the reflected beam, which in any other position is partially, or totally extinguished by the first tourmaline, and a great loss of light ensues, which it is of the utmost consequence to avoid: moreover, by this disposition, the action

of the reflector is brought to conspire with that of the tourmaline, and the polarisation of the light which traverses it (which is never rigorously exact) is thereby rendered more complete.

It is convenient to have sliding tubes containing lenses of different focal lengths according to the crystal examined, for the intensity of illumination of any point in the screen being, *cæteris paribus*, as the square of the focal length, consequently, when the rings lie within a very small angular compass, a greater illumination of every part of them may be obtained by using a lens of a longer focus.

The dimensions of the figure, Fig. 6. Pl. V. are nearly of the actual size.

Fig. 1.

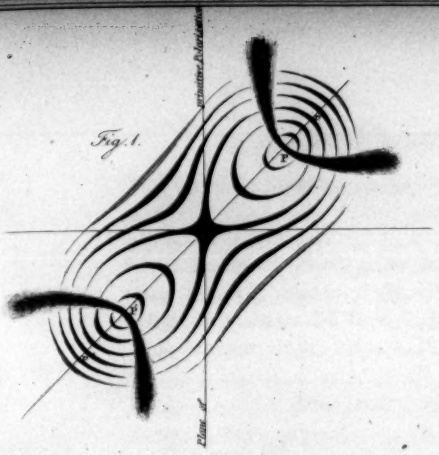


Fig. 2.

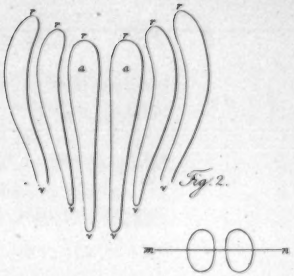


Fig. 3.

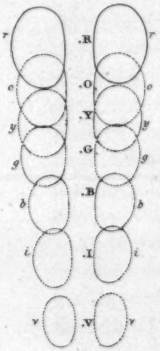


Fig. 4.

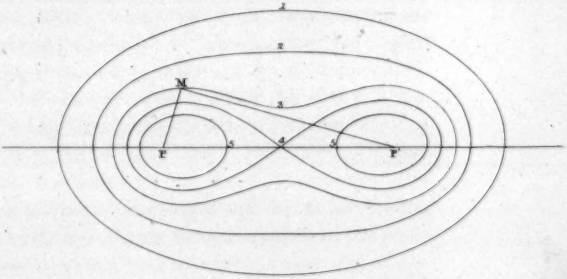


Fig. 5.

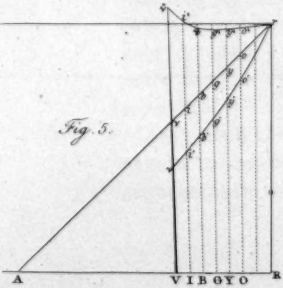
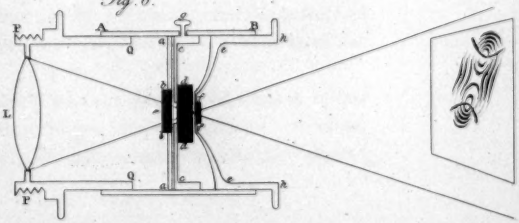


Fig. 6.



V. *A case of the human fœtus found in the ovarium, of the size it usually acquires at the end of the fourth month.* By A. B. Granville, *M. D. F. R. S. In a letter addressed to Sir* Everard Home, *Bart., V. P. R. S.*

Read January 13, 1820.

My dear Sir,

Having met with a well defined case of a fœtus in the human ovarium, which illustrates in a very satisfactory manner the explanation contained in your paper on the *corpora lutea*, respecting the mode in which the ovum is sometimes retained, and the embryo formed, within the cavity of the *corpus luteum*, I beg leave, through you, to communicate it to the Royal Society, that it may have a place amongst your observations on that subject.

To render it still more deserving of that honor, Mr. Bauer, to whom you and the public are so much indebted, has made drawings of the parts in a manner which, I may say, no one but himself could have executed.

A lady, aged 39 years, died on the 9th of last June, after having experienced various and severe sufferings, which, with the exception of a short period of apparent convalescence, had lasted from December the 19th, 1818, to the moment of her dissolution.

After death, the body was examined at the request of her friends. It presented nothing which, on a general inspection, might be said to indicate disease, except a considerable tumour,

soft and moveable, yet perfectly distinct, placed immediately above the region of the pubis, and a little to the left of the linea alba. My attention was, therefore, directed to the investigation of this point.

The integuments and muscular coverings of the abdomen being successively and carefully removed, a considerable quantity of fluid resembling blood, to the amount of several pounds, was discovered to fill every space which the viscera did not occupy. Many large coagula of pure blood lay here and there on the surface, and amongst the convolutions of the intestines; under the stomach; in the right hypochondrium principally; and in the cavity of the pelvis, where both the coagula and the fluid were in so large a quantity as completely to obscure from sight the internal parts of generation. Another obstacle to the view of these organs, even after the intestinal mass had been laid aside, was a tumour of the size of four times that of a hen's egg, partaking of the general black-reddish hue of all the surrounding parts.

A blood-vessel of the size of a large crow-quill, which penetrated the dense portion of the tumour, was traced upwards to the descending aorta, and was ascertained to be a branch of the left spermatic artery. A smaller and much shorter vessel, arising from the tumour, was also found to communicate with the spermatic vein; thus establishing a complete circulation to and from the parts. The inferior and left half portion of the tumour presented a surface consisting, in two or three places, of diaphanous membranes, through which a *fœtus* of about four months growth was readily discovered.

The fact of an extra-uterine conception being thus made out, I proceeded to detach the parts from the pelvis, and brought

them to that state of demonstration, which Mr. BAUER has so beautifully represented in the drawing (see Plate VI.)

The left ovarium (O) was the seat of the tumour, which, as it gradually enlarged, distended the coverings of that organ in the same progressive manner, in proportion to its own size, so as to remain, for a time, wholly enveloped by it.

As the fœtus however increased further, the ovarium burst in three different places (1. 2. 3) and thus the membranous sac forming the tumour, protruded partially into the cavity of the abdomen. During this destructive process, that part of the covering of the ovarium was also lacerated, over the inner surface of which the placenta (P) was engrafted, so as to tear the adhesions of the latter, thereby producing that sudden and fatal hemorrhage, which destroyed the life of the mother and the child, and filled the cavity of the abdomen with blood.

EXPLANATION OF PLATE VI.

The womb (A) had acquired considerable developement during the increase of the fœtus, so as nearly to have reached the size which it is known to attain when bearing the produce of conception. Its parietes (*a a*) were thickened in proportion; the orifice was closed, and transversely oblong, as I have generally found it to be in women who have borne children.* Several small prominent vesicles (*bb*) surrounded the internal orifice, and part of the neck of the uterus, within whose cavity (B) neither fluid, membrane, nor production of any description was found.

The right ovarium (C) was of a full size, and healthy, with

* The lady in question had been the mother of seven children. She had regularly menstruated up to December, when conception took place; and from that time there were occasional irregular discharges of a coloured fluid from the vagina.

a great number of the usual cells, containing fluid, distinctly visible; it was terminated by a long slender thread-like appendix (*c c*) of a tendinous nature, which connected it with the neighbouring viscera.

The Fallopian tube of the same side (D) was likewise healthy in its structure, but adhering to the lateral part of the *fundus uteri* by means of a short and tough band (*d*), (no doubt the result of inflammatory action), which seemed a prolongation of one of the *fimbriæ* of its floating extremity, so as to give to the tube that peculiar turn, which is so well expressed in the drawing.

The ligamenta rotunda (E E) seemed larger than usual, although healthy; and the peritoneal foldings, forming what are commonly called the large ligaments, offered not the slightest trace of disease. The latter were removed in the progress of the dissection, in order the better to exhibit the more important parts just described.

Both the Fallopian tubes were pervious only from their loose extremity inwards, to about half their length, and no farther; nor did any artifice carefully employed, enable me to discover the opening of the tubes into the womb.

The left Fallopian tube (F) was perfectly sound and loose, particularly at its fimbriated extremity, which had no connection whatever with the neighbouring tumour.

All the above anatomical and pathological features are accurately pourtrayed, and to their natural size, in the drawing, to which I beg to refer you and the Society, in order the better to comprehend my description.

It ought to be stated here, that one of my principal reasons for dissecting away the broad ligaments, was to ascertain

whether the peritoneal foldings, within which the ovarium is placed, rather than the membranes of the ovarium itself, formed the covering of the tumour. The dissection, and the drawing, prove that the latter was the case.

In order to supply as much information as possible, respecting a fact so curious and important in itself, the only one I believe on record, which offers such complete and authentic evidence of a perfect ovario-gestation, I thought it expedient to know the internal anatomy of the tumour, and readily acceded to Mr. BAUER's suggestion, of giving a second view of the case, which should represent as many of its important details as could be rightly ascertained. The result of this ulterior investigation, for which the preparation, after having been drawn in its original state, as seen by yourself, Mr. CLIFT, and others, was necessarily altered and cut into, for better demonstration, is given in a second drawing of Mr. BAUER, of the most accurate and finished execution.

I shall only give you an explanation of the references marked in that drawing, which speaks for itself.

EXPLANATION OF PLATE VII.

A. Amnion.

B. Chorion.

C C C. Placenta.

D. D. Fragments of the *corpus luteum* which surrounded the ovum, and was broken to pieces by the enlargement of the fœtus.

E E E E. Ovarium.

F. Fallopian tube.

G. A portion of the omentum adhering to the ovarium.

From the above explanation, and, on a mere reference to the plate, it appears evident,

1st. That conception took place in the ovarium.

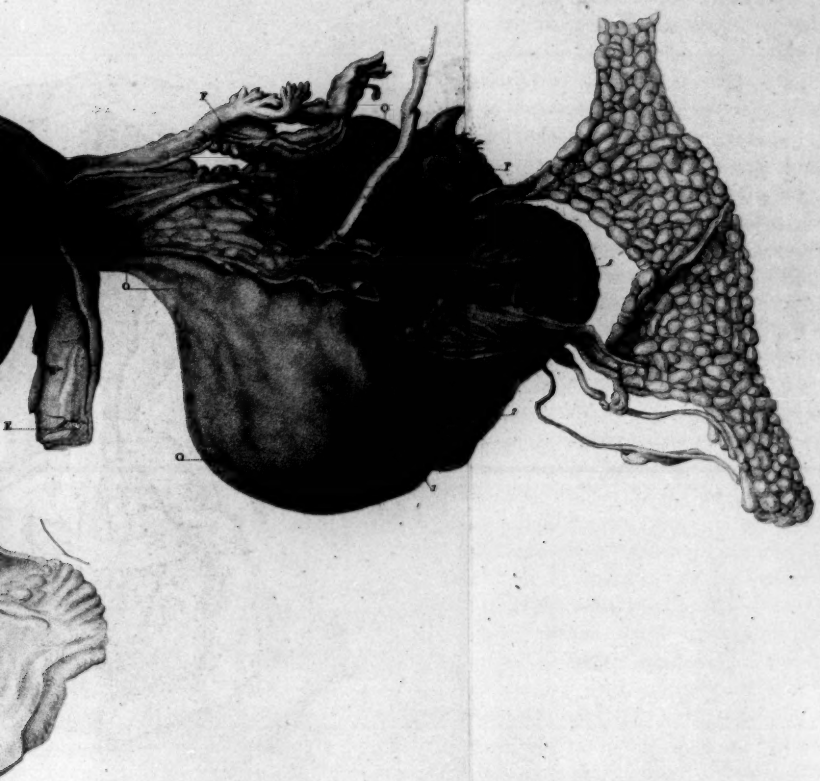
2dly. That the formation of the placenta and the developement of the fœtus, does not seem to have been different in this case, from what occurs within the womb under similar circumstances.

3dly. That the ovum was perfect, being formed of the placenta, and the two well known membranes quite distinct, without, however, the decidua of HUNTER.

4thly. That the *corpus luteum* does not follow, but precedes conception, as you have shown in the paper alluded to, since, in this case, considerable portions of the corpus luteum were still found adhering in part to the placenta. To all of which I may add, that the fœtus, in every respect as perfect as a fœtus of four months is known to be when borne in *utero*, was, in the present instance, contained in one of the outer and inferior cavities of the ovarium, within which it must have been completely inclosed, up to the period of the bursting of its covering; and that the fragments of the corpus luteum, together with the placenta, (which in this case was only half the size of what it should have been, though more vascular and spongy) adhered firmly, by means of short filaments, to the inner parietes of the cavity within which conception had taken place.

In examining the right ovarium, as well as that within which the fœtus had been developed, several cells were found, as usual, containing fluid, which hardened into small white masses by the action of alcohol, and appeared to be what anatomists have called *ova*. But having summoned the

Franz Bauer. del. 1819.



Franc. Bauer del. 1819.

J.o Basire sc.

microscopical power of Mr. BAUER to my assistance, he has enabled me to give the following explanation, consistent with your doctrine, contained in the last volume of the Philosophical Transactions.

The small round, white, and opaque bodies found in the cells of the human ovarium, as well as in that of other animals in a healthy state, after they have been immersed for some time in alcohol, consist entirely of coagulable lymph, which is easily reduced, in water, to a mass of globules like those observed in *serum*; but in the present instance, the substance of which the coagula consisted, seemed very different, it being a very strong and tenacious mucus, not soluble in water, and which, when pressed, yielded a vast quantity of oil, without the slightest appearance of any globules; a phenomenon supposed to be the effect of previous disease. In the right ovarium there was a *corpus luteum* perfectly well preserved, not far from the cells, which did not contain any such opaque white bodies; while within two other cells equally near, and containing the coagula or white bodies above described, no traces of *corpora lutea* could be discovered. I abstain from all professional observations, this not being the place to enter into them.

I am, dear Sir,

yours most truly,

A. B. GRANVILLE.

Saville Row,
June, 1819.

VI. *On some combinations of Platinum.* By Edmund Davy, *Esq. Professor of Chemistry, and Secretary to the Cork Institution. Communicated by* F. Babington, *M. D. F. R. S.*

Read February 17, 1820.

In my communication to Sir H. Davy, Bart, "On a new fulminating platinum," which has been honoured with a place in the Transactions of the Royal Society,* I stated, that I had obtained some other new compounds of this metal: these have since occupied no inconsiderable portion of my leisure hours, and I now beg leave to lay the results of my inquiry before the Royal Society. A constant attention to other necessary duties, has not allowed me sufficient time to render this investigation so complete as I could have wished; but as I presume the facts are novel, I shall venture to bring them forward in a form, which, though imperfect, may not be wholly destitute of interest.

I. *On a peculiar compound of platinum, obtained from sulphate of platinum, by the agency of alcohol.*

Sulphate of platinum, unlike the other metallic sulphates in general, is, to a considerable extent, soluble in alcohol and in ether; as these fluids are capable, in certain circumstances, of partially or wholly reviving some metallic oxides from their solutions in acids, I wished to try their effects on the sulphate of platinum. Accordingly, I put into a small phial

* Phil. Trans. 1817.

about equal volumes of a strong aqueous solution of the sulphate, and alcohol; and after agitating the mixed fluids, the phial was put aside. Some weeks afterwards, I found the dark colour of the sulphate had entirely disappeared, a dense black substance had subsided, and the supernatant fluid remained colourless and transparent. On opening the phial, an odour similar to that of ether was perceived, the fluid had a strong acid taste, and afforded a copious precipitate with nitrate of barytes. After the black substance had been well washed and dried, a few preliminary experiments, served to show that it was a peculiar compound which had not been noticed. To confirm these results, and procure more of the substance, I repeated the experiment with the sulphate and alcohol. In about two days the fluid assumed a darker tint, the black substance began to precipitate in a finely divided state, and in about a week it had all subsided, leaving the fluid colourless and transparent. I afterwards found that the substance in question may be readily obtained by boiling the sulphate and alcohol* together for a few minutes; it separates in small particles, leaving the supernatant fluid colourless, or with only a slight tinge of yellow. In cases when it is thus procured, a little volatile inflammable fluid, having a peculiar ethereal smell, is also obtained. The substance, after being washed till the water is tasteless and does not affect litmus paper, and dried at a temperature of about 250° Fahrenheit, exhibits the following properties.

* The alcohol used in this experiment, may vary considerably in its strength and quantity, without materially affecting the results. Ether may also be employed as a substitute for alcohol.

2. *Properties of the peculiar compound.*

The substance is of a black colour, and in small lumps, which are soft to the touch, and easily reduced to an impalpable powder. It readily soils the fingers, or paper. It is destitute of lustre. It is tasteless, and apparently unaffected either by cold or hot water. It has a peculiar ethereal smell that is not easily removed, and probably arises from the presence of a little inflammable matter occasioned by the action of the alcohol. It seems to undergo no change by exposure to the air for some time. When it is gently heated, on a slip of platinum or paper, a hissing noise or a feeble explosion is produced, and this effect is accompanied by a flash of red light, and the platinum is reduced. It is insoluble in nitrous, sulphuric, and phosphoric acids, but it dissolves slowly in muriatic acid. It is scarcely affected by chlorine, except moisture be present, when a little muriate is gradually formed. When the powder is put into liquid ammonia, minute globules of air are evolved from it, and after some time it acquires fulminating properties. The quantity of air I have hitherto obtained in this way, has been too small to allow me to ascertain its nature with precision. When the powder is brought in contact with ammoniacal gas, a crackling noise is produced, and it becomes red hot and scintillates; but by this treatment, its external appearance is scarcely altered, though it undergoes a partial decomposition. The powder is immediately decomposed by the agency of alcohol. This fact is shown in an interesting manner by moistening different substances, such as paper, sand, cork, &c. with alcohol, and placing the smallest particle of the powder on them; it hisses,

a sufficient degree of heat is produced to reduce and ignite the platinum, and it remains in a state of ignition until the alcohol is consumed. During the agency of alcohol on the powder, acetic acid is produced. This is shown by putting a little of the powder on a paper filter and moistening it with alcohol; a moderate action takes place, and in a few minutes, the odour of acetic acid is very perceptible. In some experiments of this kind, the action, though comparatively feeble at first, has presently increased, the powder has become red hot, and the bottom of the filter completely charred. If two or three grains of the powder are placed in a glass, and a few drops of alcohol added, in about half an hour acetic acid will be produced; and as it evaporates and disappears, it may be successively renewed, at longer or shorter intervals, for some weeks, by occasionally adding a little alcohol.

When the powder is boiled in alcohol, it is partially decomposed, and assumes a lighter colour; if it be then thrown on a filter, the odour of acetic acid is soon perceived, and in a few hours the platinum is found reduced and the paper charred. When the powder is mixed with flowers of sulphur, and heated, a sulphuret of platinum is formed of a blue colour. When the powder is heated with phosphorus, there is a brilliant combustion, and a dark grey phosphoret is formed. Oxygen gas does not affect the powder at the common temperature of the air, but by a moderate heat there is a slight combustion, which seems to indicate the presence of a little inflammable matter.

3. *Composition of the peculiar compound.*

In my first attempts to ascertain the nature of the black

powder, I was limited to very minute quantities of it; and I made several trials, before I gained any satisfactory evidences of its constitution. I decomposed the powder in long green glass tubes filled with mercury; in such cases, by a gentle heat, the powder became ignited, the reduced platinum amalgamated with the mercury, a little fluid appeared, and some gas was evolved. The fluid reddened litmus, and had an acid taste. The gas rendered lime water turbid, and was in part absorbed by water and by ammonia; and the unabsorbed portion exhibited properties similar to those of nitrogen. These results seemed to prove, that the powder contained acid and inflammable matter; but they were not sufficiently uniform to enable me to place much reliance on them. I then used very small glass retorts, varying in capacity, from $\frac{4}{10}$ to $\frac{7}{10}$ of a cubic inch, and decomposed the powder over pure water and over mercury; but the results were most satisfactory when I operated over mercury. From two experiments of this kind, which I beg briefly to detail, as they very nearly agree, I think I may venture to state the composition of the powder under examination.

Experiment 1. Ten grains of the powder were decomposed in a little retort, over dry mercury, by the heat of a spirit lamp. On the first impression of the heat, gas was disengaged, and shortly after, the interior of the retort assumed a reddish yellow colour (like that exhibited by the vapour of fuming nitrous acid), and small drops of a colourless fluid condensed in the neck of the retort. After the utmost heat of the lamp had been given to the retort, it was suffered to cool, and the results were immediately examined.

(a) Examination of the gas.

The gas remaining in the retort made an ignited piece of wood glow brighter; that which came over (deducting the common air) was $\frac{14}{100}$ of a cubic inch, which diminished to $\frac{2}{100}$ on being transferred to water and agitated. $\frac{10}{100}$ of the unabsorbed gas, on being mixed with an equal volume of pure hydrogen and fired by an electric spark, diminished to $\frac{16}{100}$. Hence, the unabsorbed portion of gas contained more oxygen than could have been furnished from the common air of the retort.

From other experiments, the gas absorbed by water was found to be carbonic acid; it rendered lime water turbid, was absorbed by ammonia, and again disengaged by muriatic acid.

(b.) Examination of the fluid.

The fluid which rose in the neck of the retort reddened litmus paper, and resembled the nitrous acid in odour, colour, and taste. It acted upon the mercury in contact with the retort, and when washed out by pure water, the solution did not affect the nitrate of barytes, or silver.

(*c.*) The platinum was perfectly reduced, and its particles formed a loosely coherent mass, which could not be removed until the bulb of the retort was broken. It weighed $9\frac{1}{2}$ grains, and suffered no diminution on being again heated to redness in a platinum cup.

Experiment 2. Ten grains of the same powder as that used in the first experiment, afforded by its decomposition $9\frac{1}{2}$ grains of platinum, a little fluid agreeing in its properties with that noticed in the former experiment, and $\frac{14}{100}$ of gas, which was examined in a different manner from that of Experiment 1. The gas remaining in the retort, was treated

with pure nitrous gas; red fumes were produced, and the absorption was so great that the mercury presently rose near the bulb of the retort, and was still rising, when its neck was intentionally broken to secure the platinum. Hence, it seems the gas in the retort was oxygen.

The gas that came over was first treated with lime-water; an immediate turbidness was produced, and increased by agitation, and $\frac{3}{100}$ of the gas were absorbed. To the residual gas, nitrous gas was added, which occasioned a considerable absorption; and the remaining gas, which exhibited the properties of nitrogen, was principally derived from the common air of the retort. By adding a little diluted muriatic acid to the turbid fluid, it immediately became transparent, and the absorbed carbonic acid was slowly disengaged, and the mercury was studded with innumerable little globules of it.

From these experiments, 100 grains of the black powder appear to contain 96·25 platinum.

3·75 nitrous acid, a little oxygen, and a minute portion of carbon.

10·000

Though the powder was dried at a heat considerably above 212°, it may contain water; and if this is the case, its composition may be differently stated, as deduced from the foregoing experiments: 96·2500 platinum.

0·1200 oxygen.

0·0106 carbon.

3·6194 nitrous acid and water.

100·0000

4. *Observations, &c. on the peculiar compound.*

From the preceding experiments, the black powder obtained by the agency of alcohol on the sulphate of platinum, appears to consist almost solely of platinum, with a little oxygen, and the elements of the nitrous acid. The very minute portion of carbonaceous matter it contains, is probably accidental. If the constitution of the powder is such as I have stated, a doubt may arise whether it can be considered as a definite compound; but its solubility in the muriatic acid, the facility with which it combines with sulphur, and resists the action of a strong solution of potash at a boiling heat, and its acquiring fulminating properties in liquid ammonia, are all circumstances which favour the notion of its being a true chemical compound. It seems rather doubtful, whether the powder can be regarded as a sub-nitrate of platinum, or a combination of platinum with oxygen and nitrogen, in a different state from that in which they co-exist in the nitrous acid. On the idea that the powder is a compound of the metal with a little oxygen and nitrous acid, something may be said on the mode of its formation, and on the more remarkable properties it exhibits.

From the manner in which the sulphate of platinum is formed, (namely, by the agency of nitrous acid on the hydrosulphuret of platinum) there can be no difficulty in accounting for the presence of a small portion of nitrous acid in it; and my experiments incline me to the opinion, that it is scarcely possible to separate the last portions of nitrous acid from the sulphate, without entirely decomposing it. That the quantity of nitrous acid in the sulphate must, however, be very

limited, appears from this circumstance, that the addition of a little nitrous acid to the sulphate, entirely prevents the formation of the black powder, though successive portions of alcohol be added, and the whole boiled for a considerable time.

When sulphate of platinum, containing a little nitrous acid, is treated with alcohol, a mutual action takes place; slowly at the common temperature of the air; but rapidly by the assistance of heat: the sulphuric acid being united to the oxide of platinum by a weak affinity, seems to form a new combination with the alcohol, whilst the oxide combines with the portion of nitrous acid present, to form the black powder. In certain cases, as is well known, alcohol separates salts from their aqueous solutions, in consequence of a stronger affinity for the water in which they are dissolved; but in this instance, the agencies of alcohol and of nitrous acid, are probably concerned in separating the sulphuric acid from the sulphate.

The vivid action of ammoniacal gas on the powder, may be referred to the mutual energy with which the alkaline gas, and loosely combined nitrous acid in the powder, act upon each other. I found by experiment, that ammoniacal gas is absorbed in this instance; thus, 3 grains of the powder were placed in a graduated glass receiver, and filled with dry mercury. 2·3 cubic inches of ammoniacal gas, containing only $\frac{1}{100}$ impurity, were let up into the receiver: an immediate action took place, the powder became ignited, and after two hours, $\frac{3}{10}$ of a cubic inch of the gas were absorbed; recently boiled pure water, whilst yet hot, was let up into the receiver, and the residual gas was all absorbed, except a small globule, which did not exceed the original impurity in the ammonia.

The action of alcohol on the powder is curious, and is connected with the decomposition of both substances. When the powder is brought in contact with the vapour of alcohol, at the common temperature of the air, there is an immediate chemical action; the heat generated is sufficient to reduce and ignite the metal, and to continue it in a state of ignition, until the alcohol is consumed. In this case, the acid first noticed by Sir H. DAVY, (in his beautiful experiment of the ignited platinum wire, and since, more fully examined by Mr. DANIELL), is produced. In other instances, the acetic acid, as has been mentioned, is formed. It would be premature to speculate on the uses to which this powder may be applied, but from its peculiar properties, there is reason to think it will admit of some useful applications. I have already employed it as an easy means of affording heat and light. To produce heat, it is only necessary to moisten any porous substance, such as sponge, cork, cotton, asbestos, sand, &c. with alcohol or whiskey, and to let a particle of the powder fall on the substance so moistened; it instantly becomes red hot, and remains so until the spirit is consumed; nor is the ignited metal extinguished by exposure to the atmosphere, or by blowing the breath on it; on the contrary, partial currents of air only make it glow brighter. The heat produced in this way, may be accumulated to a considerable extent, by increasing the quantity of the materials employed. I have also constructed a tinder box, to procure immediate light by means of the powder. It consists of two small phials placed in a japanned box, and some sulphur matches tipped with phosphorus. One of the phials contains the powder; the other, alcohol. The stopper of the phial containing the alcohol,

has a bit of sponge inserted in a small aperture at the bottom of it. When a light is wanted, it is only necessary to shake the bottle so as to moisten the sponge with the alcohol, take out the stopper, and put the smallest particle of the powder on the moistened sponge; it instantly becomes red hot, and will readily kindle one of the matches. This mode of igniting a metal seems to be quite a new fact in the history of chemistry; but the means of keeping it in a state of ignition, is only another illustration of the facts previously pointed out by Sir H. DAVY, in his late valuable researches, which have thrown so much light on the philosophy of flame, and led to such very interesting, important, and unexpected results.

5. *On the effects of sulphate of platinum upon gelatine.*

When an aqueous solution of sulphate of platinum is added to any solution of gelatine, such as isinglass, size, or glue, a precipitate occurs, and all the sulphate is separated in union with the gelatine; or if a minute portion remain, it is precipitated on boiling the fluid. This precipitate, whilst in a moist state, is of a brown colour, and has some degree of tenacity; but when well washed and dried at a temperature a little above the boiling point of water, its colour changes to a jet black; it becomes hard and brittle, and has a resinous lustre. It is not decomposed by being boiled in water or in weak alkaline solutions. When it is gently heated by a spirit lamp on a slip of platinum, a violent action is produced, and a dense white vapour is exhaled, in which the odour of sulphureous acid is perceptible, the substance becomes ignited, and is presently decomposed, leaving the reduced platinum in small grains.

When this compound is decomposed by heat in close vessels over water or mercury, it yields a grey sulphuret of platinum,* nitrogen, sulphureous, carburetted hydrogen and carbonic acid gases, carbonate of ammonia, and an oily-like fluid. This compound of sulphate of platinum and gelatine, when dried at a heat just above that of boiling water, afforded, by its decomposition in two experiments, half its weight of platinum; and if my former statement of the composition of sulphate of platinum is correct, 100 grains of the above compound will consist of about

56·11	oxide of platinum,
20·02	sulphuric acid,
23·87	gelatine and water.
100·00	

6. On the sulphate of platinum, as a test for gelatine.

As I found that minute quantities of gelatine in solution, were readily detected by the sulphate of platinum, I made some experiments to ascertain the efficacy of this substance as a test for gelatine, and I am inclined to think it merits a decided preference over the re-agents at present used by chemists for this purpose. The best known substances for detecting the presence of gelatine are, I presume, those which contain the tanning principle, as the infusions of oak-bark, nutgalls, catechu, &c. And a variety of gelatine, isinglass, (as is well known), is employed to ascertain the quantity of

* In the "Annales de Chimie," &c. Tome V., M. VAUQUELIN treats of the sulphuret of platinum as a new compound which he had formed; but I published an account of it in the Philosophical Magazine, in the year 1812.

tanning principle in different astringent substances; but for this purpose, as Sir H. DAVY has shown,* many precautions are necessary; and from his experiments it appears that tannin may exist in a state of combination, in which its presence cannot be made evident by means of a solution of gelatine. I have made several comparative experiments on the efficacy of those astringent infusions, and of the sulphate of platinum, as tests for gelatine; and I think I may venture to conclude, that the sulphate is a test of superior delicacy, and more certain in its operation. Thus, in cases where the gelatine was in very minute quantity, or in a very diluted state, when no effect was produced by strong infusions of oak-bark, nutgalls, or catechu, there was an immediate precipitate on adding sulphate of platinum. In instances also, when the quantity of gelatine was too minute to be readily detected by simply adding the sulphate, the effect was immediately produced on boiling the fluid.

The effects of sulphate of platinum on solutions of the different varieties of gelatine, as isinglass, glue, and size, appear to be precisely similar, and the precipitates obtained in such cases, seem to be uniform in their properties and composition; nor are they affected by the presence of any of the mineral acids in excess. The operation of astringent infusions, as oak-bark, nutgalls, and catechu, on solutions of the different varieties of gelatine, is not uniform. According to Sir H. DAVY, catechu contains a much larger quantity of the tanning principle than oak-bark; yet I found that an infusion of it produced no precipitate in solutions of size, of different degrees of concentration. The size I employed was

* Phil. Trans. 1803.

such as paper-hangers use; it had been recently prepared, and was, previous to its being dissolved in water, in the form of a tremulous jelly. The sulphate of platinum occasions, after a short time, a brown precipitate in astringent infusions; but this substance I have not examined.

7. *On a grey oxide of platinum.*

In the course of my experiments to ascertain the composition of fulminating platinum, I treated it with nitrous acid, and thus procured, as I have elsewhere stated, a grey oxide of platinum, which has not yet been described. It may be obtained by adding strong nitrous acid to fulminating platinum, boiling it to dryness, and exposing the dry mass to a heat just below redness, so as to expel all the nitrous acid. The oxide of platinum remains. It is to be finely pulverized and boiled, first in pure water, and then in a weak solution of caustic alkali to separate the last portions of acid, which adhere with great tenacity to it. It is now to be well washed and dried at a heat not exceeding that of boiling mercury. I have usually made the experiment in a platinum crucible on a hot sand bath. The oxide thus prepared exhibits the following properties.

8. *Properties and composition of the grey oxide of platinum.*

Its colour is dark iron grey. It has the metallic lustre. It is sufficiently hard to cut brass, which it polishes, and when the polished surface is rubbed a little with the oxide, a delicate coating of platinum remains. It does not touch steel. It is not affected by cold or hot water, nor by the nitrous, sulphuric, or phosphoric acid at a boiling heat. It is insoluble

in nitro-muriatic acid, and in cold muriatic acid, but it slowly dissolves in this last acid by the assistance of heat. It is not acted upon by a strong solution of the fixed alkalies. When the oxide is put into liquid ammonia, minute globules of air are evolved from it, but the quantity has been too small to admit of being examined; probably it is common air, as the oxide appears to undergo no change by being kept for some weeks in ammonia. When heated with sulphur, the oxide yields sulphureous acid gas and a grey sulphuret of platinum. When mixed with zinc filings and heated, the oxide is decomposed with vivid ignition, and white oxide of zinc is formed.

When the oxide is mixed with borax, and exposed to a strong red heat before the blowpipe, it forms a black glass, which becomes of a lighter colour on urging the heat to whiteness, and the oxide appears to be reduced. If the oxide is mixed with powdered glass and fused, a glass is obtained of a dull brown colour. The oxide is readily reduced by moistening it with oil of turpentine, and heating it moderately; or by exposing it to a dull red heat in the atmosphere; but it requires a strong red heat to reduce it in close vessels. Some of the oxide which had been well dried, first on a hot sand bath, and then exposed to a heat just below redness, on a slip of platinum, was decomposed in very small green glass retorts, over mercury. In two experiments in which I used 7 grains of the oxide, I obtained in each instance 6 grains of platinum, and 0·1 cubic inches of oxygen, the thermometer being at 60° and barometer 30°. I found also in the necks of the retorts, a slight trace of a fluid that reddened litmus paper, and had an odour similar to that of nitrous acid. Now, if

6 grains of platinum combine with 2·1 cubic inches of oxygen, 100 grains will take 34 cubic inches; and calculating from Sir H. DAVY's statement, that 100 cubic inches of oxygen weigh 34 grains, the grey oxide of platinum will be found to consist of

$$\left.\begin{array}{l}100 \text{ platinum} \\ 11{\cdot}9 \text{ oxygen}\end{array}\right\} \text{ or per cent, of } \begin{array}{l}89{\cdot}366 \text{ platinum,} \\ 10{\cdot}634 \text{ oxygen.}\end{array}$$

$$100{\cdot}000$$

It will be readily seen, that I have here deduced the composition of the grey oxide from the actual quantity of oxygen and metal obtained in the experiments; and this mode of analysis seems liable to little objection, and can very rarely be resorted to, in ascertaining the composition of metallic oxides. On comparing my previous experiments upon the grey oxide, with the above results, I am most inclined to place confidence in the latter. There is, indeed, a near coincidence between them, and the difference, which is only about one per cent, may be referred to the presence of a little more acid in my first experiments. The grey oxide is insoluble in aqua regia, a fact which seems to add additional support to Sir H. DAVY's opinion respecting the action of aqua regia on platinum.* This menstruum, according to Sir H. DAVY, does not oxidate platinum, but merely causes its combination with chlorine. Now, if the metal were oxidated previous to its solution, the oxygen, there is reason to think, would be derived from the nitrous acid, and the grey oxide formed by this acid, be produced, which can scarcely

* Journal of Science and the Arts, Vol. I.

be the case, as it is insoluble in aqua regia. Add to this, the fact, that by evaporating a common solution of platinum to dryness, no nitrate can be obtained, but only a muriate, or a compound of the metal and chlorine.

If, according to the statements of Professors VAUQUELIN and BERZELIUS, the black oxide of platinum contains about 15 per cent. of oxygen, the grey oxide may be considered as the protoxide, containing 1 proportion, and the black oxide $1\frac{1}{2}$ proportion of oxygen; and the number representing the element or proportion in which platinum combines with bodies will be 126, taking Sir H. DAVY's number 15, to represent the proportion in which oxygen unites with bodies.

Mr. COOPER states the black oxide of platinum to consist of 100 platinum, with only 4·317 of oxygen;* but he has, I think, considerably under-rated the oxygen in it. On repeating his experiments on a small scale, I obtained results different from those he has stated. Thus, he says the powder obtained from the muriate of platinum by a neutral solution of mercury, is a compound of calomel and the protoxide of platinum; but by decomposing this powder in a little retort over mercury, I found the neck of the retort partially lined with metallic mercury; and this fact alone, I think, is sufficient to awaken suspicion as to the accuracy of his results. Mr. COOPER, I presume, used a nitrate of mercury to decompose the muriate of platinum, but he seems to have overlooked the nitrous acid in stating his results.

The chemical history of platinum, is far from being complete. The great want of uniformity in the statements of

* Journal of Science and the Arts, Vol. III.

chemists respecting the composition of the known compounds of this valuable metal, and the circumstance of their not harmonizing with the doctrine of definite proportions, prove the necessity of submitting them to a more rigid examination; and this could not be done without rendering our information on the subject more accurate and extensive.

Cork Institution,
Sept. 1, 1819.

VII. *On the methods of cutting rock crystal for micrometers.* By WILLIAM HYDE WOLLASTON, *M. D. F. R. S.*

Read February 24, 1820.

FOR the mere purpose of examining the phenomena of double refraction, it is extremely easy for any skilful workman to combine a wedge of rock crystal, or any other doubly refracting substance, with another wedge of crown glass opposed to it, in such a manner that a luminous object seen through them shall appear in its true place by ordinary refraction, accompanied by a second image at a small distance, produced by the extraordinary refraction of the crystal.

In consequence of the dispersion of colours which occurs in employing different substances, the above combination is not suited for the purpose of the micrometer invented by the Abbé ROCHON; but it is not difficult to obtain such a section of rock crystal as may be substituted for the wedge of glass, so that the pencil of light shall be restored to its original direction void of colour, without diminishing the separation of the images occasioned by the first wedge.

But since the degree to which the double refraction of rock crystal separates the two portions of a beam of light transmitted through it, is not so great as may frequently be wished, it becomes desirable to increase this effect beyond what can be produced by the most obvious method of employing that substance; and it does appear from M. ROCHON's own account

of his contrivance,* that he fully succeeded in accomplishing this end. But although he informs us that the means employed, as best suited to his views, had exactly the effect of doubling the amount of deviation produced by ordinary means, he has not chosen to explain the mode of construction he adopted, and has merely referred to a certain artist living at that time in Paris, who was in possession of his secret, and skilful in applying it to the construction of micrometers.

As I have reason to think that the method to which he alludes in his memoir has never yet been described, I design, in the present communication, to explain a combination which I have found advantageous, and which I think must be the same as that of M. ROCHON.

I shall hope to render the principles of this construction intelligible to every one acquainted with the original observation of HUYGENS on the properties of polarised light, and to enable any competent artist to cut wedges from hexagonal prisms of rock crystal, in the positions requisite to produce, by their combination, the double effect to which I allude.

There are three principal directions in which a crystal may be cut specifically different from each other, which require to be distinctly understood.

In the first place, let us suppose a prismatic crystal to be placed with its axis in a vertical position, and a portion to be cut off from the base by a plane surface at right angles to the axis, and sufficient to form a wedge of 20 degrees, by giving it a second surface duly inclined to the former. For distinction, this may be called the *horizontal* wedge.

Next, let the crystal be bisected vertically by a plane

* Journal de Physique, An. 9.

passing through two opposite edges of the prism, in order to make two other wedges which are to be cut in different directions from the two portions, and to have each the same angle of 20 degrees.

Let one of the halves thus obtained be slit in a plane which meets the surface of bisection in one of the edges of the original prism, and consequently, in a line parallel to the axis. The wedge thus formed may be called a *lateral* wedge.

Let the remaining half be cut by another plane not vertical, but inclined to the vertical plane at an angle of 20°, and meeting it in a line parallel to the base, or at right angles to the axis. This may be called a *vertical* wedge.

We have thus three wedges cut in different directions at right angles to each other, and, accordingly, having their axes of crystallization differently placed in each.

In the first, or horizontal wedge, the axis is at right angles to the first surface. In the second, or lateral wedge, the axis is parallel in the first surface, and parallel to its acute edge. In the third, or vertical wedge, the axis is also in the first surface, but it is at right angles to the acute edge.

An object seen through the first wedge in the direction of the axis, does not appear double; but, since rays transmitted through the second or third, pass at right angles to the axis, both of these wedges give two images of any object seen through them.

There are obviously three modes in which these wedges may be combined in pairs, by placing two of them together with their acute edges in opposite directions. The first pair may be represented by L H; the second by V H; the third by V L. In the two first cases

the separation of the images will be the same, since the angles of all the wedges are supposed to be made equal, the compound medium will be comprised under parallel surfaces, so that a ray ordinarily refracted by both, emerges in its original direction; but since the extraordinary ray is made to deviate about 17 minutes from the ordinary course by the wedge which refracts doubly, this difference is not corrected by the horizontal wedge, so that an object seen through either of the combinations L H or V H, appears doubled to the amount of 17′.

The third combination, consisting of the vertical and lateral wedges combined, as in the former cases, with their acute edges in opposite directions, produces an effect perfectly distinct from either of the former combinations; for by reason of the transverse position of their axes of crystallization, the separation of the two images becomes exactly doubled. The consequence of that position is, that the pencil ordinarily refracted by the first wedge, is refracted extraordinarily by the second, and that which has been refracted extraordinarily by the first, suffers a similar interchange, and is now ordinarily refracted, so that neither of the divided pencils returns to its true place; and since one falls as much short of the mean as the other exceeds the truth, they emerge ultimately separated twice the usual difference between the ordinary and extraordinary refractions, and thus present two images separated 34 minutes, just double of that which is effected by either of the preceding combinations.

Though it could scarcely be doubted that this is essentially the construction which was employed by M. Rochon, there is an additional circumstance concerning the effect of such a

pair of wedges when otherwise combined, which fully establishes the identity of the method here proposed with his. If the two wedges be placed with their edges together, so as to form by their union a wedge of 40°, the consequence is, that though a pencil of light is in fact divided into two parts by the first wedge, both parts in the end emerge together; the refraction of one being $o + e$, and of the other $e + o$: they both deviate from their original direction by exactly the same quantity, and present only a single image of the luminous object; but it is coloured, as usual, in proportion to the amount of deviation occasioned by the sum of the wedges. This, without doubt, is the first of two opposite directions mentioned by M. ROCHON, in which he says the double refraction was not perceptible.

" Pour cet effet," says M. ROCHON, " j'employai deux " prismes égaux taillés dans le sens le plus favorable a mes " vues, et en les présentant dans les deux sens opposés je " trouvai, que dans la première disposition la double réfrac- " tion n'étoit pas perceptible, mais, en faisant prendre à mes " prismes un sens inverse, la double réfraction de chaque " prisme étoit presque doublée."

The correspondence in the effect which I have described, renders this passage from M. ROCHON perfectly intelligible; and I hope the directions above given will be sufficient to enable any one to cut a crystal to the greatest advantage for making this sort of micrometer. But it must be observed, that in attempting such a construction, great nicety is requisite, not only in cutting the wedges so that the refraction in each shall take place at right angles to the axis, but also in cementing them together, so that the axes of the two wedges

shall be at right angles to each other. And it may farther be remarked, that even then, unless the pencil of light pass truly in the common plane of refraction of the wedges, four images will be formed, so as to destroy the effect of the combination.

From the Press of
W. BULMER & Co.
Cleveland-row, St. James's,
London.

METEOROLOGICAL JOURNAL,

KEPT AT THE APARTMENTS

OF THE

ROYAL SOCIETY,

BY ORDER OF THE

PRESIDENT AND COUNCIL.

MDCCCXX.

METEOROLOGICAL JOURNAL

for January, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Jan. 1	8	0	32	44	30,48	2½	34		W	1	Dark and hazy.
	2	0	37	51	30,49	3	38		SSW	1	Dark and cloudy.
2	8	0	33	44	30,48	5	34		S	1	Thick fog.
	2	0	36	49	30,46	3	39		S	1	Thick fog.
3	8	0	37	44	30,35	7	39		S	1	Fine.
	2	0	38	46	30,31	10	42		S	1	Fine.
4	8	0	35	43	30,21	7	34		SE	1	Fine.
	2	0	40	52	30,18	11	40		SE	1	Fair.
5	8	0	33	59	30,17	7	32		W	1	Thick fog.
	2	0	41	51	30,20	6	39		SE	1	Cloudy.
6	8	0	37	47	30,20	6	38		SW	1	Cloudy, and hazy.
	2	0	42	56	30,16	12	45		SE	1	Fine.
7	8	0	41	48	29,91	8	39		SE	1	Cloudy.
	2	0	45	53	29,78	15	46		SSE	1	Cloudy.
8	8	0	37	51	29,88	7	39		W	1	Fine.
	2	0	42	57	29,92	17	42		NW	1.2	Fine.
9	8	0	48	51	29,58	10	41		S	1.2	Cloudy.
	2	0	45	55	29,56	10	51		S	1	Cloudy.
10	8	0	45	50	29,91	9	42		SW	2	Cloudy.
	2	0	48	50	29,75	8	49		S	3	Cloudy.
11	8	0	43	50	29,70	16	44		S	1.2	Cloudy.
	2	0	46	56	29,84	28	46		WSW	1	Cloudy.
12	8	0	39	49	30,13	17	39		SW	1	Fine.
	2	0	48	55	30,15	17	49		SW	1	Fine.
13	8	0	40	50	30,01	7	41		S	1	Fine.
	2	0	47	57	29,93	12	47		S	2	Cloudy.
14	8	0	48	51	29,95	4	40		S	1.2	Rain.
	2	0	52	57	29,88	10	52		W	1.2	Rain.
15	8	0	43	52	30,02	8	44		W	1	Cloudy.
	2	0	49	59	29,92	7	52		NW	1	Cloudy.
16	8	0	36	49	30,20	13	38		NW	1.2	Fine.
	2	0	43	57	30,29	20	44		S	1	Fine.

Rain this Month 0,789 Inches.

METEOROLOGICAL JOURNAL

for January, 1819.

1819	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Sia's Therm.		Winds. Points.	Winds. Str.	Weather.
Sep. 17	8	0	47	51	29,50	6	42		WSW	2	Rain.
	2	0	48	51	29.35	25	52		WSW	1.2	Fine.
18	8	0	40	49	29.37	12	39		W	2	Cloudy.
	2	0	41	55	29.57	18	45		W	1	Fine.
19	8	0	37	49	29,78	14	37		W	1	Cloudy.
	2	0	43	55	29.82	17	44		W	1	Cloudy.
20	8	0	37	51	29,58	11	38		SW	1	Cloudy.
	2	0	43	59	29.60	22	45		Wby N	1	Fine.
21	8	0	36	41	29.49	13	37		W	1	Fine.
	2	0	43	55	29,52	25	44		WSW	1	Fine.
22	8	0	38	51	29,53	11	39		SW	1	Cloudy.
	2	0	47	55	29.42	15	49		SE	1	Cloudy.
23	8	0	38	50	29,58	13	39		SW	1	Fine.
	2	0	45	57	29.56	26	48		SW	1	Fine.
24	8	0	42	50	29,61	3	41		SE	1	Fine.
	2	0	47	50	29,42	15	60		SE	1	Fine.
25	8	0	40	49	29,43	8	40		S	2	Cloudy.
	2	0	43	53	29,22	7	44		SSE	3	Rain.
26	8	0	41	51	29,40	7	42		S	1	Cloudy.
	2	0	45	55	29,44	7	47		SW	1	Cloudy.
27	8	0	43	52	29 46	3	41		SE	1	Cloudy and thick fog.
	2	0	46	53	29.47	2	50		SE	1	Cloudy.
28	8	0	46	50	29,35	9	44		SSE	1	Cloudy.
	2	0	46	56	29,42	10	46		S by E	1	Cloudy.
29	8	0	38	53	29,53	3	39		SE	1	Cloudy and hazy.
	2	0	45	60	29,50	28	47		SSE	1.2	Fine.
30	8	0	40	52	29,36	8	40		E	1.2	Rain.
	2	0	42	56	29,35	4	44		E	1	Cloudy and hazy.
31	8	0	39	51	29,47	5	38		N	1	Cloudy.
	2	0	43	51	29,51	12	44		SE	1	Cloudy.

Rain this Month 0,789 Inches.

METEOROLOGICAL JOURNAL

for February, 1819.

1819	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Winds. Str.	Weather.
Feb. 1	8	0	31	47	29,60	5	31		W	1	Fine.
	2	0	40	56	29,61	30	40		W	1	Fine.
2	8	0	36	47	29,54	4	35½		E	1	Dark with snow.
	2	0	37	49	29,66	12	38			1	Cloudy.
3	8	0	30	47	29,72	8	30		NW	1	Hazy.
	2	0	39	51	29,61	11	40		S by E	1	Cloudy.
4	8	0	37	48	29,56	11	36		W	1	Fine.
	2	0	44	52	29,70	14	44		W	1	Cloudy.
5	8	0	39	50	29,73	5	39		E	1	Rain.
	2	0	45	56	29,06	4	46		S by E	1	Rain.
6	8	0	43	51	29,61	6	45		W	1	Fine.
	2	0	48	55	29,64	15	52		W	1	Cloudy.
7	8	0	39	50	29,44	5	40		WSW	1	Fine.
	2	0	46	51	29,41	18	54		NW	1	Cloudy.
8	8	0	36	48	29,80	8	37		W	1	Fine.
	2	0	45	55	29,96	18	47		N	1	Fine.
9	8	0	44	50	29,94	3	41		SW	1	Cloudy.
	2	0	48	56	29,88	5	58		NW	1	Cloudy.
10	8	0	45	51	29,74	14	46		NW	1	Fine.
	2	0	49	51	29,99	28	49		W	1	Fine.
11	8	0	45	50	30,04	12	42		W	1.2	Cloudy.
	2	0	51	57	30,03	19	54		W	1	Fine.
12	8	0	45	52	29,73	13	46		W	2	Cloudy.
	2	0	44	57	29,60	13	49		W	1.2	Rain.
13	8	0	37	51	29,75	8	39		W	1	Fine..
	2	0	46	56	29,78	13	49		W	1	Hail.
14	8	0	35	50	29,30	10	35		W	1	Fine, rather hazy.
	2	0	40	53	30,04	34	42		S	1	Fine.

Rain this Month 1,638 Inches

METEOROLOGICAL JOURNAL

for February, 1819.

1818	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Winds. Str.	Weather.
Feb. 15	8	0	36	48	30,04	11	35		W	1	Cloudy and hazy.
	2	0	46	56	30,93	14	46		SW	1	Cloudy.
16	8	0	43	50	29,68	13	40		S	2	Cloudy.
	2	0	43	55	29,57	6	46		S	2	Rain.
17	8	0	48	52	29,42	17	44		SW	1.2	Cloudy.
	2	0	52	58	29,56	30	52		W	1	Fine.
18	8	0	43	53	29,51	10	43		N	1	Hazy.
	2	0	48	58	29,64	18	50		W	1	Cloudy. [night.
19	8	0	47	54	29,24	10	44		S	3	Rain, a very stormy
	2	0	50	59	29,39	23	52		W	2	Cloudy.
20	8	0	37	53	29,83	7	37		WSW	1	Fine.
	2	0	46	58	29,88	21	52		SW	1	Fine.
21	8	0	43	52	29,18	20	41		E	1.2	Rain.
	2	0	46	52	29,02	7	48		W	1	Rain.
22	8	0	40	50	29,75	11	40		N	1	Cloudy.
	2	0	45	55	29,89	20	46		N	1	Fine.
23	8	0	38	53	29,59	7	38		S	1	Rains hard.
	2	0	43	55	29,51	19	45		SW	1	Cloudy.
24	8	0	34	49	29,65	14	33		SW	1	Hazy.
	2	0	41	54	29,47	27	44		SW	1	Cloudy. [yesterday even.
25	8	0	34	47	29,70	10	28		E by S	1	Cloudy, much snow
	2	0	41	54	29,78	10	43		SE	1	Fine.
26	8	0	32	49	29,70	11	31		N	1	Cloudy.
	2	0	36	53	29,55	8	39		E	1	Rain.
27	8	0	37	48	29,89	12	35		E	1	Cloudy.
	2	0	43	55	29,38	10	45		SW	1	Cloudy.
28	8	0	40	48	29,30	9	39		SW	1	Cloudy.
	2	0	40	48	29,31	7	41		SE	1	Cloudy.

Rain this Month 1,638 Inches.

METEOROLOGICAL JOURNAL
for March, 1819.

1818	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Mar. 1	7	0	36	46	29.21	6	36		SSE	1,2	Rain and sleet.
	2	0	40	51	29,22	6	41		N	1	Rain.
2	7	0	41	48	29,30	6	38		E	1	Rain.
	2	0	44	54	29,41	5	45		SE	1	Cloudy.
3	7	0	39	47	29,53	15	37		E	1	Cloudy.
	2	0	40	50	29,65	17	41		E	1	Cloudy.
4	7	0	37	46	29,89	16	36		NE	1	Cloudy.
	2	0	45	56	29,88	14	46		NNE	1	Cloudy.
5	7	0	41	50	29,98	4	38		N	1	Cloudy.
	2	0	45	56	29,97	17	46		NE	1	Cloudy.
6	7	0	43	51	29,87	6	41		E	1	Cloudy.
	2	0	47	56	29,91	27	57		SSE	1	Fine.
7	7	0	40	50	30,07	10	39		E	1	Cloudy.
	2	0	45	51	30,09	5	47		SE	1	Cloudy.
8	7	0	40	49	30,10	10	39½		E	1	Cloudy.
	2	0	46	53	30,09	22	46		NE	1	Cloudy.
9	7	0	39	48	30,09	15	38½		ESE	1	Cloudy.
	2	0	47	53	30,11	5	48		SW	1	Fine.
10	7	0	40	48	30,10	10	37		NW	1	Cloudy and hazy.
	2	0	46	52	30,05	15	47		NW	1	Cloudy.
11	7	0	43	50	30,05	15	40		NW	1	Cloudy.
	2	0	49	57	30,08	10	55		SW	1	Cloudy.
12	7	0	45	53	30,14	18	43		NW	1	Cloudy.
	2	0	49	53	30,16	26	51		W	1	Cloudy.
13	7	0	46	53	30,27	7	44		NW	1	Cloudy.
	2	0	48	57	30,29		50		NW	1	Cloudy.
14	7	0	43	52	30,30	27	43		W by S	1	Cloudy.
	2	0	46	54	30,19	30	50		SW	1	Fine.
15	7	0	39	51	30,18	15	37				Thick fog.
	2	0	51	59	30,12	35	52		W	1	Fine.
16	7	0	48	54	30,02	10	44		W$W	1,2	Cloudy.
	2	0	57	59	30,03	30	57		W	1,2	Cloudy.

Rain this Month 1,010 Inches.

METEOROLOGICAL JOURNAL
for March, 1819.

1819	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Fly-gro-meter.	Six's Therm.		Winds. Points	Winds. Str.	Weather.
Mar. 17	7	0	45	53	30,10	15	43		W	1.2	Fine.
	2	0	53	61	30,14	36	54		W	1.2	Fine.
18	7	0	39	51	30,21	19	36		N	1	Fine.
	2	0	53	60	30,17	37	55		SW	1	Fine.
19	7	0	44	54	29,51	4	39		S	1.2	Rain.
	2	0	48	60	29,51	23	50		NW	1	Fine.
20	7	0	43	54	29,42½	14	41		SW	2	Cloudy.
	2	0	47	62	29,56	14	47		NW	2	Rain.
21	7	0	41	54	29,77	22	40		NNE	1	Fine.
	2	0	46	54	29,79	20	56		NW	1	Fine.
22	7	0	40	51	29,81	14	39½		SW	1	Cloudy.
	2	0	51	59	29,81	39	49		W	1	Cloudy.
23	7	0	42	53	29,75	14	40		S	1	Cloudy and hazy.
	2	0	49	57	29,73	7	52		S	1	Cloudy.
24	7	0	47	52	29,56	5	43		SW	1	Cloudy.
	2	0	54	57	29,62	40	57		W	1	Fine.
25	7	0	47	51	29,51	11	46		SW	1	Cloudy.
	2	0	51	58	29,83	32	55		W	1.2	Fine.
26	7	0	45	54	29,88	16	39		W	1	Fine.
	2	0	55	58	29,95	42	53		W	1	Cloudy.
27	7	0	47	53	29,86	15	47		W	1.2	Cloudy.
	2	0	48	56	29,77	14	55		W	1.2	Rain.
28	7	0	46	55	29,78	5	46		W	1	Rain.
	2	0	48	55	29,74	7	54		W	1	Cloudy.
29	7	0	50	54	29,72	50	47		W	1	Fine.
	2	0	54	61	29,97	24	55		W	1	Showery and squally.
30	7	0	46	56	29,62	13	49		WSW	2	Cloudy.
	2	0	57	61	29,99	16	60		WSW	1	Cloudy.
31	7	0	52	57	29,09	13	50½		W	1	Cloudy.
	2	0	57	63	30,11	9	60		WbyN	1.2	Cloudy.

Rain this Month 1,019 Inches.

METEOROLOGICAL JOURNAL

for April, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Apr. 1	7	0	51	56	30,16		48		SW	1	Fine.
	2	0	61	64	30,17	26	63		SW	1	Fine.
2	7	0	52	61	30,16	13	49		W	1	Fine.
	2	0	61	66	30,14	48	63		NW	1	Fine.
3	7	0	50	60	30,05	22	52		S	1	Fine.
	2	0	65	66	29,99	37	67		W	1	Fine.
4	7	0	45	59	30,16	17	48		E	1	Cloudy.
	2	0	55	60	30,14	25	62		SE	1	Fine.
5	7	0	50	61	30,07	12	47		NE	1.2	Cloudy.
	2	0	54	66	30,06	41	65		N	1	Fine.
6	7	0	44	58	29,95	22	41½		E	1	Fine.
	2	0	52	64	29,82	22	55		SE	1	Fine.
7	7	0	47	58	29,58	11	54		SE	1	Cloudy.
	2	0	57	66	29,71	26	62		SE	1	Fair.
8	7	0	54	61	29,85	17	54		SSE	1	Cloudy.
	2	0	55	62	29,91	7	56		N	1	Rain.
9	7	0	48	59	29,99	14	46		N	1	Fine.
	2	0	57	61	30,02	25	51		SE	1	Cloudy.
10	7	0	45	56	30,01	14	43		W	1	Cloudy.
	2	0	58	64	29,84	33	62		SW	1	Fine.
11	7	0	48	59	29,46	12	45		W	1	Cloudy.
	2	0	56	60	29,35	29	58		W	1	Fine.
12	7	0	45	56	29,33	5	45½		SW	1	Rain.
	2	0	48	57	29,31	7	54		SE	1	Rain.
13	7	0	52	58	29,21	6	49		S	1	Cloudy.
	2	0	52	58	29,29	16	55		WSW	1	Fine.
14	7	0	47	57	29,49	11	44		S	1.2	Cloudy.
	2	0	53	62	29,49	35	58		S	1	Fine.
15	7	0	48	56	29,41	9	46		NW	1	Fine.
	2	0	57	62	29,45	22	58		NE	1	Fine.
16	7	0	49	57	29,11	10	46		NE	1.2	Cloudy.
	2	0	55	65	29,22	24	57		NE	1	Fine.

Rain this Month 1,010 Inches.

METEOROLOGICAL JOURNAL
for April, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Apr. 17	7	0	47	57	29,36	13	43		S	2	Rain.
	2	0	49	63	29,45	34	55		NE	1	Fine.
18	7	0	48	56	29,63	24	45		W	1.2	Fine.
	2	0	52	57	29,61	20	59		WNW	1	Fine.
19	7	0	46	55	29,82	21	41		W	1	Fine.
	2	0	52	61	29,81	8	57		SSE	2	Cloudy.
20	7	0	52	57	29,68	3	50		W	1	Dark and Cloudy.
	2	0	57	61	29,70	11	58		S	1	Cloudy.
21	7	0	50	58	29,64	14	48		W	1.2	Cloudy.
	2	0	56	62	29,57	12	59		SW	1	Fine.
22	7	0	48	56	29,81	52	45		SE	1	Fine.
	2	0	50	60	29,90	20	50		NNE	1	Cloudy.
23	7	0	46	56	29,81	5	45		SE	1	Cloudy.
	2	0	50	57	29,73	16	51		SE	1	Fine.
24	7	0	48½	56	29,58	3	47		ENE	1	Rain.
	2	0	46	57	29,58	5	53		ESE	1	Cloudy.
25	7	0	48	55	29,71	4	46		NNW	1	Cloudy.
	2	0	48	55	29,85	10	49		ESE	1	Cloudy.
26	7	0	44	52	30,11	18	38½		N	1	Fine.
	2	0	50	55	30,13	20	52		ESE	1	Fine.
27	7	0	45	52	30,14	15	41		NE	1	Fine.
	2	0	47	60	30,18	30	59		SE	1	Fine.
28	7	0	39	53	30,22	15	41		ESE	1	Fine.
	2	0	52	61	30,19	50	56		E	1	Fine.
29	7	0	48	55	30,07	20	42½		ESE	1	Fine.
	2	0	52	61	30,02	46	55		ESE	1	Fine.
30	7	0	46	54	29,94	15	42		ESE	1	Fair.
	2	0	56	69	29,59	44	58		ESE	1	Fine.

Rain this Month 1,694 Inches.

METEOROLOGICAL JOURNAL

for May, 1819.

1819		Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
May	1	7	0	49	55	29,84	17	43		SE	1	Fine.
		2	0	56	62	29,84	56	62		SW	1	Fine.
	2	7	0	52	57	29,75	25	43		SE	1	Fine.
		2	0	49	60	29,68	34	65		NW	1	Fine.
	3	7	0	49	56	29,56	20	41		N	1	Fine.
		2	0	60	62	29,56	40	69		SE	1	Fine.
	4	7	0	50	61	29,47	17	40		S	1	Fine.
		2	0	61	61	29,52	47	65		SSE	1	Fine.
	5	7	0	50	61	29,56	19	40		SE	1	Fine.
		2	0	61	63	29,55	22	63		SSW	1	Fine.
	6	7	0	49	57	29,49	18	40		S	1	Fine.
		2	0	60	65	29,97	25	65		SE	1	Fine.
	7	7	0	52	56	29,48	16	42		SSE	1	Fine.
		2	0	61	63	29,54	27	66		SE	1	Fine.
	8	7	0	48	54	29,51	18	44		S	1	Fine.
		2	0	62	64	29,53	30	69		SE	1	Fine.
	9	7	0	55	56	29,53	10	45		SSE	1	Fine.
		2	0	68	65½	29,58	34	71		SW	1	Fine.
	10	7	0	56	62	30,17	19	50		SSW	1	Fine.
		2	0	65	65	30,17	30	70		SW	1	Fine.
	11	7	0	68	64	30,06	19	64½		W	1	Fine.
		2	0	62	62½	30,07	34	66½		NW	1	Fine.
	12	7	0	61	60	30,08	16	56		W	1	Fine.
		2	0	62½	63	30,04	28	67		W	1	Fine.
	13	7	0	59½	61	30,04	21	66		SW	1	Fine.
		2	0	61	62	30,06	36	65		NW	1	Fine.
	14	7	0	53	59	30,03	24	52		SWb N	1	Fine.
		2	0	61	63	30,01	43	64		W	1	Fine.
	15	7	0	57	57½	30,13	23	54		SW	1	Fine.
		2	0	60	52	30,15	40	65		S	1	Fine.
	16	7	0	55	58½	30,17	17	52		SSW	1	Fine.
		2	0	59	61	30,21	36	64		SE	1	Fine.

Rain this Month 1,400 Inches.

METEOROLOGICAL JOURNAL

for May, 1819.

1819	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Winds. Str.	Weather.
May 17	7	0	55	58½	30,17	17	52		SSE	1	Fine.
	2	0	64	65	29,91	46	67		NE	1	Fine.
18	7	0	62	60	29,68	10	51		SW	1	Fine.
	2	0	63	63	29,10	30	68		W	1	Fine.
19	7	0	55	59	29,12	5	54		E	1	Rain.
	2	0	60	61	29,16	15	62		NE	1	Rain.
20	7	0	58	59	29,16	9	66		W	1	Rain.
	2	0	63	64	29,19	19	64		SW	1	Rain.
21	7	0	54	58	29,14	18	56		S	1	Fine.
	2	0	59	60	29,17	34	67		E	1	Fine.
22	7	0	66½	58	29,55	10	51		S	1	Fair.
	2	0	61	61½	29,52	17	64		S	1	Showery.
23	7	0	58	59½	29,91	16	50		ESE	1	Fine.
	2	0	60	63	29,91	24	58		SE	1	Fine.
24	7	0	57	61	29,84	12	51		SE	1	Rain.
	2	0	61	61	29,84	17	63		SE	1	Fine.
25	7	0	53	55½	29,63	4	50		E	1	Fair.
	2	0	60	62	29,68	7	63		E	1	Fine.
26	7	0	54	58	29,51	5	51		SE	1	Fine.
	2	0	58	59	29,81	11	61½		WSW	1	Fine.
27	7	0	49	56	29,73	6	51		E by N	1	Fine.
	2	0	56	59	29,64	14	62		E	1	Fine.
28	7	0	46½	55	29,91	8	51		SW	1	Fine.
	2	0	53	56	29,93	19	58		SSW	1	Fine.
29	7	0	51	52	29,62	16	52		NE	1	Fine.
	2	0	59	56	29,62	18	55		SWbN	1	Fine.
30	7	0	59	66	29,84	12	52½		SW	1	Fine.
	2	0	49	53	29,84	20	67		S	1	Fine. [night.
31	7	0	58	55½	29,08	17	55		SW	1	Cloudy, rain in the
	2	0	57	57	29,08	21	61		NE	1	Fine.

Rain this Month 1,400 Inches.

METEOROLOGICAL JOURNAL

for June, 1819.

1819	Time.		Therm. without.	Therm. within.	Barom.	Hygrometer.	Six's Therm.		Winds.		Weather.
	H.	M.	°	°	Inches.				Points.	Str.	
June 1	7	0	57	56	30,08	10	51		SW	1	Fine.
	2	0	61	58	29,95	19	67		SW	1	Fine.
2	7	0	58	57	29,95	10	54		SSW	1	Fine.
	2	0	69	61	30,01	25	67		SSW	1	Fine.
3	7	0	56	58	30,01	10	50		SW	1	Fine.
	2	0	64	61	29,99	24	67		SW	1	Fine.
4	7	0	59	59	29,93	10	56		SW	1	Fine.
	2	0	64	62	29,91	14	68		WSW	1	Fine.
5	7	0	54	59	30,01	9	48		WSW	1	Fine.
	2	0	64	63	30,06	17	68		WSW	1	Fine.
6	7	0	56	59	30,04	8	51		SW	1	Fine.
	2	0	63	64	29,93	27	68		WSW	1	Fine.
7	7	0	58	60	29,62	10	51		WSW	1	Fine.
	2	0	63	61½	29,63	32	66		SW	1	Fine.
8	7	0	58	60	29,60	16	51½		S	1	Fine.
	2	0	59	63	29,58	19	66		S	1	Fine.
9	7	0	57	61	29,58	10	54		NW	1	Fine.
	2	0	66	66	29,61	36	67½		S	1.2	Fine.
10	7	0	55	61½	29,67½	19	53		W	1	Fine.
	2	0	63	65	29,74	15	67		SW	1	Showery.
11	7	0	53	61	29,96	11	48		W	1	Fine.
	2	0	62	62	29,98	17	67		SSW	1	Fine.
12	7	0	54	60	30,00	13	49		SWbyS	1	Fine.
	2	0	62	63	30,01	25	64		SW	1	Fair.
13	7	0	55	59	30,07	16	49		SW	1	Hazy.
	2	0	65	62	30,03	39	69		SSW	1	Fine.
14	7	0	55	60	29,99	11	51		W	1	Fine.
	2	0	63	62	29,93	22	65		SW	1	Cloudy.
15	7	0	51	60	29,78	15	55		S by W	1 2	Rain.
	2	0	62	63	29,76	20	64		N	1	Cloudy.
16											

Rain this Month 1,017 Inches.

METEOROLOGICAL JOURNAL

for June, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
June16	7	0	54	59	29,92	12	46½		SSE	1	Cloudy.
	2	0	62	61	29,94	26	63		N	1	Cloudy.
17	7	0	57	59	30,06	11	51		W	1	Cloudy.
	2	0	63	63	30,07	28	66		S	1	Fine.
18	7	0	56	61	30,04	3	55½		N	1	Hazy.
	2	0	60	61½	30,02	15	62		ENE	1	Cloudy.
19	7	0	58	61	30,10	18	54		N	1	Fine.
	2	0	66	67	30,13	37	70		NE	1	Fine.
20	7	0	60	63	30,19	16	55		S	1	Fair.
	2	0	66	66	30,28	39	68		SSE	1	Fine.
21	7	0	51	62	30,18	23	58		N	1	Fine.
	2	0	70	70	30,12	29	72		SE	1	Fine.
22	7	0	56	64	30,07	19	56		W	1	Fine.
	2	0	65	65	30,05	26	69		NE	1	Fine.
23	7	0	60	64	30,03	16	58		NW	1	Cloudy, rather hazy.
	2	0	66	67	30,01	19	70		N	1	Cloudy.
24	7	0	57	63	29,89	10	54		W	1	Rain.
	2	0	58	63	29,78	6	64		SW	1.2	Cloudy.
25	7	0	60	64	29,76	4	57		W	1	Cloudy, dull weather.
	2	0	63	64	29,77	10	66		SW	1	Cloudy.
26	7	0	57	62	29,65	4	55		S	2	Cloudy.
	2	0	62	62	29,64	10	67		S	1	Cloudy.
27	7	0	59	59½	29,69	5	51		SSW	1	Cloudy.
	2	0	60	66	29,58	12	64		SW	1	Rain.
28	7	0	53	60	29,67	9	51		NW	1	Fair.
	2	0	59	63	29,70	23	63		NW	1	Cloudy. a storm of thunder, lightning, and hail at noon.
29	7	0	54	58	29,82	14	47½		NW	1	Fine.
	2	0	62	60	29,85	11	65		SSW	1	Fine.
30	7	0	58	60	29,75	5	55		W	1	Cloudy.
	2	0	64½	62	29,72	23	68		WNW	1	Fine.

Rain this Month 1,017 Inches.

METEOROLOGICAL JOURNAL

for July, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
July 1	7	0	56	60	29,79	25	50½		W	1	Fine.
	2	0	65	61	29,82	30	65		NW	1	Cloudy.
2	7	0	56	60	29,88	13	51		SW	1	Fair.
	2	0	62	61	29,87	18	67		WSW	1	Rain.
3	7	0	60	61	29,78	9	56		SW	1	Cloudy.
	2	0	69	65	29,81	20	71		WSW	1	Fine.
4	7	0	61	64	29,76	19	60		S	1	Cloudy.
	2	0	74	72	29,81	27	81		WSW	1	Fine.
5	7	0	66	66	29,84	10	62		W	1	Fine.
	2	0	71½	71	29,85	30	78		S	1	Fine.
6	7	0	63	66	29,94	13	62		S	1	Thick and hazy.
	2	0	63	66	29 92	10	69		SE	1	Rain.
7	7	0	62	66	30,12	12	61		N	1	Hazy.
	2	0	67	67	30,15	30	69		W	1	Fine.
8	7	0	62	65	30,01	8	60		N	1	Rain.
	2	0	64	65	29,98	12	67		SE	1	Cloudy.
9	7	0	59	64	30,08	10	60		W	1	Cloudy.
	2	0	69	68	30,12	49	70		WNW	1	Fine.
10	7	0	59	63	30,12	20	56		W	1	Cloudy.
	2	0	66	67	30,06	30	70		WNW	1	Fine.
11	7	0	61	64	30,08	18	53		W	1	Cloudy.
	2	0	66	65	30,08	39	70		WNW	1	Fine.
12	7	0	66	65	30,09	20	57		W	1	Fine.
	2	0	71	68	30,09	23	74		WSW	1	Fine.
13	7	0	64	64	30,17	20	62		S	1	Cloudy.
	2	0	66	65	30,18	36	71		S	1	Fine.
14	7	0	59	64	30,16	27	56		SSE	1	Fine.
	2	0	64	65	30,12	19	68		S	1	Fine.
15	7	0	58	63	30,05	18	57		N	1	Dull and Cloudy.
	2	0	64	65	30,02	22	68		N	1	Fine.
16	7	0	58	63	30,00	23	56½		E	1	Cloudy.
	2	0	68	69	30,01	27	72		E	1	Fine.

Rain this Month 0,750 Inches.

METEOROLOGICAL JOURNAL
for July, 1819.

1819	Time.	Therm. without.	Therm. within.	Barom.	Hygrometer.	Six's Therm.		Winds.		Weather.
	H. M.	°	°	Inches.				Points.	Str.	
July 17	7 0	62	64	29,99	15	56		N	1	Cloudy.
	2 0	71	67	30,01	27	71		NW	1	Cloudy.
18	7 0	63	65	30,00	14	61		W	1	Fine.
	2 0	65	68	29,84	30	65		W	1	Fine.
19	7 0	62	64	29,68	15	58		SSW	1	Fine.
	2 0	61	71	29,59	48	76		W	1	Fine. [night.
20	7 0	63	67	29,32	31	61		S	1	Cloudy, rain in the
	2 0	66	68	29,33	31	74		SW	1	Fine.
21	7 0	57	65	29,46	14	56		SSE	2	Cloudy.
	2 0	63	64	29,58	5	61		NE	2	Cloudy.
22	7 0	57	63	29,95	19	54		S	1	Fine.
	2 0	65	67	30,07	40	69		S	1	Fine.
23	7 0	59	63	30,14	17	55		W	1	Hazy.
	2 0	69	69	30,15	61	70		N	1	Fine.
24	7 0	65	65	30,18	23	61		N	1	Fine, but rather hazy.
	2 0	69	70	30,16	35	79		N	1	Fine.
25	7 0	66	65	30,10	16	59		E	1	Fine.
	2 0	68	72	30,07	29	74		SE	1	Fine.
26	7 0	65	67	30,02	14	59		NNE	1	Fine, rather hazy.
	2 0	70	72	30,03	35	74		SW	1	Fine.
27	7 0	58	66	30,12	20	63		N	1	Cloudy.
	2 0	72	72	30,13	42	73		N	1	Fine.
28	7 0	63	67	30,19	16	61		NbyE	1	Cloudy and hazy.
	2 0	70	73	30,21	40	74		S	1	Fine.
29	7 0	63	66	30,17	17	49		S	1	Cloudy, rather hazy.
	2 0	74	73	30,11	42	77		WSW	1	Fine.
30	7 0	67	67	30,10	25	61		N	1	Fine.
	2 0	75	77	30,09	37	79		E	1	Fine.
31	7 0	69	68	30,02	18	65		E	1	Fine.
	2 0	72	74	30,01	38	78		S	1	Fine.

Rain this Month 0,750 Inches.

METEOROLOGICAL JOURNAL
for August, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.	Winds. Points.	Str.	Weather.
Aug. 1	7	0	68	68	30,01	13	66	W	1	Cloudy and hazy.
	2	0	69	71	30,01	49	80	N	1	Fine.
2	7	0	62	66	30,00	15	61	SE	1	Cloudy.
	2	0	69	73	29,95	34	72	W	1	Fine.
3	7	0	63	68	29,91	29	61	N	1	Cloudy.
	2	0	65	67	29,92	48	71	N	1	Fine.
4	7	0	63	66	29,88	17	62	N	1	Cloudy.
	2	0	66	66	29,89	16	68	NW	1	Fine.
5	7	0	63	67	29,92	16	62	N	1	Cloudy.
	2	0	66	67	29,95	18	67½	NNW	1	Fine.
6	7	0	62	67	29,99	16	59½	NW	1	Fine.
	2	0	72	70	29,97	21	75	W	1	Cloudy.
7	7	0	66	66	29,98	13	62	NW	1	Cloudy and hazy.
	2	0	73	71	29,99	50	73	SW	1	Fine.
8	7	0	64	65	30,05½	24	61	NE	1	Cloudy.
	2	0	67	67	30,08	30	70	NE	1	Fine.
9	7	0	66	66	30,11	20	60	N	1	Fine.
	2	0	72	72	30,12	36	76	NNE	1	Fine.
10	7	0	64	66	30,11	16	61	E	1	Fine.
	2	0	68	72	30,08	24	73	SSE	1	Fine.
11	7	0	63	64	30,00		59	E	1	Cloudy and hazy.
	2	0	68	70	29,95	33	74	SE	1	Fine.
12	7	0	62	64	29,92	23	61	ESE	1	Cloudy and hazy.
	2	0	74	71	29,90	43	76	W	1	Fair.
13	7	0	64	65	29,92	15	62	W	1	Cloudy.
	2	0	72	69	29,92	24	74	WSW	1	Cloudy.
14	7	0	65	66	30,01	24	63	NE	1	Cloudy and hazy.
	2	0	69	68	30,03	34	72	E	1	Cloudy.
15	7	0	64	65	30,08	20	59½	N	1	Fine.
	2	0	72	70	30,08	37	73	SSW	1	Fine.
16	7	0	68	67	30,16	21	67	N	1	Fine.
	2	0	73	76	30,18	62	74	NW	1	Fine.

METEOROLOGICAL JOURNAL

for August, 1819.

1819	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Winds. Str.	Weather.
Aug. 17	7	0	65	67	30,22	20	64		NNE	1	Fine.
	2	0	75	75	30,25	60	78		E	1	Fine.
18	7	0	62	65	30,29	10	65		ENE	1	Cloudy.
	2	0	71	73	30,31		74		NE	1	Fine.
19	7	0	64	65	30,23	14	63		E	1	Hazy.
	2	0	69	68	30,19	35	72		ESE	1	Fine.
20	7	0	63	64	30,18	20	61		N	1	Cloudy and hazy.
	2	0	69	69	30,19	44	71		NE	1	Fine.
21	7	0	63	66	30,22	13	61		NbE	1	Fine, rather hazy.
	2	0	71	73	30,19	48	73		NE	1	Fine.
22	7	0	64	64	30,15	18	62		NE	1	Cloudy and hazy.
	2	0	70	68	30,13	37	73		ENE	1	Fine.
23	7	0	66	66	30,11	10	64		NNE	1	Fine.
	2	0	72	75	30,11	57	74		S	1	Fine.
24	7	0	66	68	30,06	12	62		N	1	Fine.
	2	0	73	75	30,06	73	76		SE	1	Fine.
25	7	0	66	68	29,96	16	62		NbE	1	Fine.
	2	0	74	74	29,95	60	75½		S	1	Fine.
26	7	0	65	67	30,05	18	62		NbE	1	Fair.
	2	0	70	69	30,06	41	71		N	1	Cloudy.
27	7	0	63	67	30,05	14	60		NE	1	Cloudy.
	2	0	70	68	30,05	22	72		SE	1	Fine.
28	7	0	63	68	29,97	12	61		E	1	Cloudy.
	2	0	68	68	29,88	27	72		SbyE	1	Cloudy.
29	7	0	63	66	29,71	5	59		SW	1	Cloudy.
	2	0	71	72	29,56	29	74		S	1	Fine.
30	7	0	63	66	29,41	7	59		SE	1	Cloudy.
	2	0	69	67	29,20	10	70		E	1	Rain.
31	7	0	55	63	29,31	13	52		SW	1	Fair.
	2	0	67	67	29,39		67				

Rain this Month 0,250 Inches.

METEOROLOGICAL JOURNAL

for September, 1819.

1819	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.	Winds. Points.	Winds. Str.	Weather.
Sept. 1	7	0	50	57	29,48	18	47	W	1	Fine.
	2	0	61	62	29,55	54	62	SW	1	Fine.
2	7	0	52	57	29,67	17	48	W	1	Fine.
	2	0	64	66	29,71	50	67		1	Fine.
3	7	0	63	64	29,61	2	63	W	1	Cloudy.
	2	0	68	68	29,72	40	71	WSW	1	Fine.
4	7	0	58	61	29,91	8	54	W	1	Fine.
	2	0	67	68	29,96	37	70	W	1	Fine.
5	7	0	63	64	29,77	7	62	NW	1	Rain.
	2	0	63	65	29,81	27	67	W	1	Fine.
6	7	0	55	60	29,91	16	51	W	1	Fine.
	2	0	62	67	30,01	48	65	W	1	Fine.
7	7	0	60	64	30,05	7	55	SW	1	Cloudy.
	2	0	68	65	30,06	56	69	SW	1	Fine.
8	7	0	65	65	30,09	16	62	WSW	1	Fine.
	2	0	71	69	30,10	28	73	W	1	Fine.
9	7	0	64	65	30,12	8	62	S	1	Cloudy.
	2	0	69	72	30,12	44	72	SW	1	Fine.
10	7	0	63	66	29,99	10	61	E	1	Cloudy and hazy.
	2	0	68	71½	30,06	39	70	S	1	Fine.
11	7	0	60	64	30,07	8	57	N	1	Thick hazy weather.
	2	0	60	64	30,12	30	66	N	1	Cloudy.
12	7	0	59	60	30,21	17	58	SW	1	Cloudy.
	2	0	68	70	30,23	37	76	S	1	Fine.
13	7	0	57	61	30,27	22	53	N	1	Hazy.
	2	0	66	70	30,27	51	66	E	1	Fine.
14	7	0	58	63	30,25	8	55	E	1	Thick and hazy.
	2	0	66	71	30,21	54	69	SE	1	Fine.
15	7	0	62	65	29,98	9	58	E	1	Cloudy, rather hazy.
	2	0	70	70	29,87	34	73	SSW	1	Fine.

Rain this Month 1,320 Inches.

METEOROLOGICAL JOURNAL
for September, 1819.

1819	Time. H. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Sept. 16	7 0	57	63	29,69	11	57		N	1	Cloudy.
	2 0	63	64	29,74	38	67		NW	1	Fine.
17	7 0	54	59	29,96	14	48		N	1	Fine.
	2 0	63	64	30,06	27	69		N	1	Fine.
18	7 0	55	59	30,19	7	53		W	1	Cloudy.
	2 0	65	67	30,17	30	68		W	1	Fine.
19	7 0	57	61	30,19	28	52		SW	1	Fine.
	2 0	60	62	30,19	36	66		W	1	Fine.
20	7 0	52	56	30,29	15	47½		N	1	Fine
	2 0	70	63	30,34	40	70		NE	1	Fine.
21	7 0	51	56	30,44	18	47		NbyE	1	Fine.
	2 0	60	62	30,44	39	66		N	1	Fine.
22	7 0	51	57	30,45	22	48		N	1	Fine.
	2 0	60	61	30,36	27	66		E	1	Cloudy.
23	7 0	57	59	30,23	16	53		N	1	Fine.
	2 0	59	60	30,10	24	62		E	1	Cloudy.
24	7 0	54	58	29,87	20	53		ESE	1	Cloudy and hazy.
	2 0	61	63	29,78	40	63		SE	1	Fine.
25	7 0	56	59	29,59	5	52		E	1	Rain.
	2 0	58	61	29,52	7	62		E	1	Rain.
26	7 0	60	67	29,48	17	52		E	1	Fair.
	2 0	60	62	29,58	32	62		NW	1	Fine. [night.
27	7 0	56	59	29,55	5	52		W	1	Fine. Rain in the
	2 0	63	62	29,60	13	64		W	1	Rain.
28	7 0	60	61	29,59	11	58		S	3	Rain.
	2 0	60	63	29,61	19	65		S	1	Fair.
29	7 0	59	61	29,47	5	56		S	2.3	Rain.
	2 0	61	63	29,61	11	65		W	1	Cloudy.
30	7 0	61	62	29,77½	11	56		W	1.2	Cloudy.
	2 0	60	63	29,79	19	64		W	1	Cloudy.

Rain this Month 1,320 Inches.

METEOROLOGICAL JOURNAL

for October, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Oct. 1	8	0	63	63	29,80	17	61		S	2	Fine.
	2	0	69	65	29,75	17	69		SW	1	Cloudy.
2	8	0	61	64	29,58	6	60		SbyE	1.2	Cloudy.
	2	0	68	68	29,75	42	68		W	1	Fine.
3	8	0	61	64	29,72	16	58		W	1	Cloudy.
	2	0	63	67	29,67	40	63		W	1	Fine.
4	8	0	58	63	29,54	12	54		S	1.2	Cloudy.
	2	0	57	63	29,56	15	57		SW	1	Rain.
5	8	0	46	59	29,81	21	44		NW	1	Fine.
	2	0	58	62	30,04	34	58		NW	1	Fine.
6	8	0	47	56	30,13	14	43		W	1	Cloudy.
	2	0	55	58	30,01	27	55		SW	1.2	Fine.
7	8	0	54	58	29,91	10	53		W	1	Cloudy, rather hazy.
	2	0	58	62	29,87	25	58		SW	1	Cloudy.
8	8	0	58	60	30,00	6	56		W	1	Cloudy.
	2	0	59	61	30,03	19	59		W	1	Fair.
9	8	0	57	60	29,93	8	57		SbyE	1	Cloudy.
	2	0	58	61	29,80	20	58		S	1	Cloudy.
10	8	0	60	61	29,78	11	58		WSW	1	Cloudy.
	2	0	60	67	29,81	44	60		W	1	Fine.
11	8	0	62	63	29,83	60	60		E	1	Fine.
	2	0	66	68	29,92	35	66		ESE	1	Fine.
12	8	0	59	63	29,98	13	56		NNE	1	Thick and hazy.
	2	0	70	70	29,99	25	70		SW	1	Fine.
13	8	0	61	64	29,97	2	59		S	1	Cloudy and hazy.
	2	0	64	65	29,95	20	64		SW	1	Cloudy.
14	8	0	54	60	30,08	13	51		SW	1	Cloudy and hazy.
	2	0	60	62	30,10	13	60		W	1	Rain.
15	8	0	57	60	30,27	12	51		NbyE	1	Fine.
	2	0	57	62	30,31	38	57		SE	1	Fine.
16	8	0	53	57	30,26	14	47		W	1	Cloudy and hazy.
	2	0	57	60	30,01	19	57		W	1	Cloudy.

Rain this Month 1,069 Inches.

METEOROLOGICAL JOURNAL

for October, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Oct. 17	8	0	44	54	30,11	19	42		NW	1	Fine.
	2	0	50	54	30,16	22	55		N	1	Rain.
18	8	0	43	52	30,20	8	42		N	1	Fine.
	2	0	50	54	30,21	30	54		SW	1	Fine.
19	8	0	39	52	30,13	5	37		W	1	Cloudy.
	2	0	47	55	30,01	25	60		W	1	Fine.
20	8	0	54	55	29,67	5	37		SW	1	Cloudy.
	2	0	53	55	29,57	10	57		SW	1	Rain.
21	8	0	42	49	29,48	8	44		NbW	1	Cloudy and hazy.
	2	0	42	51	29,52	0	42		NW	1	Cloudy, snow at 10 o'clock.
22	8	0	34	47	29,41	3	32½		NNE	1.2	Cloudy, a heavy fall of snow in the night.
	2	0	42	49	29,42	12	43		NW	1.2	Rain.
23	8	0	37	47	29,35	3	37		W	1	Fair.
	2	0	54	55	29,31	10	54		W	1	Cloudy.
24	8	0	47	48	29,32	7	38		W	1	Cloudy.
	2	0	46	48	29,35	4	49		W	1.2	Cloudy.
25	8	0	36	46	29,41	12	35		W	1	Cloudy.
	2	0	43	52	29,47	8	43		NW	1	Fine.
26	8	0	40	49	29,56	4	34		N	1	Cloudy and hazy.
	2	0	48	57	29,58	6	60		NW	1	Fine.
27	8	0	34	51	29,81	1	32		NbyW	1	Hazy and thick.
	2	0	43	55	29,79	6	45		SbyE	1	Rain.
28	8	0	37	50	29,80	3	36		NNE	1	Fine.
	2	0	45	56	29,79	7	45		N	1	Fine.
29	8	0	37	52	29,57	1	35		N	1	Cloudy and hazy.
	2	0	43	53	29,48	7	44		NbyE	1	Cloudy.
30	8	0	42	52	29,54	2	40		NE	2	Rain.
	2	0	45	55	29,57	8	45		SW	1	Rain.
31	8	0	43	52	29,78	0	44		E	1	Rain.
	2	0	45	50	29,23	7	48		E	1	Cloudy.

Rain this Month 1,089 Inches.

METEOROLOGICAL JOURNAL

for November, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Nov. 1	8	0	45	50	29,35	0	45		E	1	Rain.
	2	0	47	57	29,77	6	51		NbyE	1	Cloudy.
2	8	0	42	51	29,59	0	41		NE	1	Fine.
	2	0	46	59	29,61	10	47		WNW	1	Fine.
3	8	0	39	55	29,90	6	37		NW	1	Fine.
	2	0	45	59	30,09	25	46		SW	1	Fine.
4	8	0	43	53	29,96	12	39		W	1	Fine.
	2	0	51	58	29,91	18	56		SSW	1	Cloudy.
5	8	0	49	56	29,74	16	46		SW	1	Cloudy.
	2	0	52	59	29,82	19	60		S	1	Cloudy.
6	8	0	46	57	29,52	7	46		W	1	Fine.
	2	0	52	62	29,47	17	53		SW	1	Fine.
7	8	0	44	55	29,41	11	43		S	1	Fine.
	2	0	53	55	29,47	22	54		S	1	Fine.
8	8	0	39	53	29,55	3	38		N	1	Fine.
	2	0	46	59	29,59	11	56		N	2	Cloudy.
9	8	0	33	53	29,88	1	33		W	1	Fine.
	2	0	47	56	29,85	13	49		W	1	Cloudy.
10	8	0	44	56	29,34	1	34		W	1	Thick and hazy.
	2	0	49	60	29,32	17	51		NW	1	Cloudy.
11	8	0	45	57	29,58	4	45		N	2	Cloudy.
	2	0	46	57	29,75	11	48		S	1 2	Cloudy.
12	8	0	46	59	29,90	3	45		NE	1	Cloudy.
	2	0	48	59	29,95	12	48		N	1	Fine.
13	8	0	43	54	29,82	10	41		N	1	Cloudy.
	2	0	45	57	29,81	16	47		N	1	Cloudy.
14	8	0	43	54	29,79	9	42		S	1	Cloudy.
	2	0	47	56	29,79	15	48		S	1	Cloudy.
15	8	0	42	52	29,78	0	42		W	1	Foggy.
	2	0	46	61	29,70	3	49		S	1	Cloudy.
16	8	0	42	52	29,54	0	42		NW	1	Rain.
	2	0	56	64	29,48	12	57		SW	1	Cloudy.

Rain this Month 0,917 Inches.

METEOROLOGICAL JOURNAL
for November, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Nov. 17	8	0	41	51	29,61	2	39		E	1	Cloudy.
	2	0	44	58	29,80	10	45		N	1	Cloudy.
18	8	0	42	54	30,05	15	42		E	1	Cloudy.
	2	0	45	56	30,08	19	46		E	1	Cloudy.
19	8	0	35	49	29,99	14	34		NE	1	Fine.
	2	0	39	55	29,99		40		S	1	Fine.
20	8	0	35	48	29,74	9	34		NW	1	Cloudy.
	2	0	38	53	29,58	12	42		W	1	Cloudy.
21	8	0	38	49	29,11	3	35		W	1	Fine.
	2	0	42	49	29,14	8	44		W	1	Cloudy.
22	8	0	33	46	29,49	3	33		W	1	Fine, but hazy.
	2	0	40	54	29,54	11	40		N	1	Fine.
23	8	0	31	48	29,74	6	21		W	1	Fine, hoar frost.
	2	0	38	54	29,78	13	43		W	1	Fine.
24	8	0	29	47	29,88	2	28½		W	1	Fine.
	2	0	48	52	29,96	5	38		NW	1	Fine.
25	8	0	32	47	30,01	1	31		W	1	Fine, rather hazy.
	2	0	44	53	29,95	8	39		W	1	Fine.
26	8	0	37	48	29,66	3	35		NNW	1	Thick fog.
	2	0	41	52	29,73	0	42		NbyW	1	Dark and cloudy.
27	8	0	37	52	29,90	0	37		N	1	Damp, dark and hazy.
	2	0	40	55	29,93	12	44		SW	1	Rain.
28	8	0	34	49	29,89	0	30		N	1	Cloudy.
	2	0	33	54	29,79	9	35		W	1	Cloudy.
29	8	0	47	47	29,57	0	33		S	1	Cloudy.
	2	0	50	53	29,51	0	52		SW	2	Rain.
30	8	0	50	42	29,59	0	51		SSW	1.2	Rain.
	2	0	51	58	29,59	5	52		SW	1	Cloudy.

Rain this Month 0,917 Inches.

METEOROLOGICAL JOURNAL

for December, 1819.

1819	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Dec. 1	8	0	47	53	29.73	4	47		WbyN	1	Rain
	2	0	48	57	29.94		51		SW	1	Fine.
2	8	0	47	52	29.98	8	40		S	2	Cloudy.
	2	0	48	59	29.93	0	50		W	1	Rain.
3	8	0	35	53	30.17	0	34		S	1	Fine, rather hazy.
	2	0	46	57	30.17	11	43		S	1	Fine.
4	8	0	42	52	29.51	0	40		S	3	Rain.
	2	0	45	57	29.78	0	48		S	2	Rain.
5	8	0	40	52	29.87	7	41		N	2	Cloudy.
	2	0	47	51	29.92	12	49		N	1	Cloudy.
6	8	0	37	50	30.04	8	37		E	1.2	Cloudy.
	2	0	39	53	30.07		39		E	1	Cloudy.
7	8	0	35	58	30.03	3	35		N	1	Cloudy.
	2	0	47	55	30.01	3	52		N	1	Cloudy.
8	8	0	30	47	30.01	7	31		SSE	1	Cloudy.
	2	0	31	52	30.05	4	52		SSE	1	Fine.
9	8	0	27	43	30.07	3	26		NE	1	Cloudy.
	2	0	31	49	30.07	10	31		N	1	Cloudy. [the night.
10	8	0	30	46	29.89	2½	28½		N	1.2	Cloudy, and snow in
	2	0	32	49	29.84	6	32		W	1	Cloudy.
11	8	0	18	43	30.01		18		W	1	Fine, but hazy.
	2	0	30	48	30.01	15	29		W	1	Fine.
12	8	0	34	43	29.96	4	32		W	1	Cloudy.
	2	0	36	43	29.88	9	36		N	1	Cloudy.
13	8	0	28	42	29.78	0	28		N	1	Cloudy.
	2	0	35	48	29.75	3	36		W	1	Cloudy.
14	8	0	26	43	29.74		25½		W	1	Fine, rather hazy.
	2	0	37	48	29.62	7	38		W	1	Cloudy.
15	8	0	33	44	29.46	4	31		W	1.2	Fine.
	2	0	43	48	29.46	13	39		W	1	Cloudy.
16	8	0	32	44	29.81	2	32		W	1	Fine.
	2	0	38	48	29.95	15	41		W	1	Cloudy.

Rain this Month 1.875 Inches.

METEOROLOGICAL JOURNAL
for December, 1819.

1819	Time. H. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.	Six's Therm.		Winds. Points.	Str.	Weather.
Dec. 17	8 0	37	49	29,71	1	34		E	2.3	Rain, a stormy night.
	2 0	43	51	29,45	3	43		E	2	Rain.
18	8 0	51	51	29,35	1	43		W	1	Cloudy.
	2 0	49	54	29,46	11	54		NW	1	Cloudy.
19	8 0	48	53	29,52	5	50		WNW	1	Cloudy.
	2 0	42	53	29,75	9	45		SW	1	Cloudy.
20	8 0	52	53	29,64	0	51		W	1	Rain.
	2 0	50	60	29,64	7	54		W	1	Cloudy.
21	8 0	44	53	29,93	9	44		W	1	Cloudy.
	2 0	45	57	29,89	0	48		SE	1	Rain.
22	8 0	51	56	29,49	5	43		W	2	Cloudy.
	2 0	55	60	29,71	17	54		W	1	Cloudy.
23	8 0	49	56	29,24	7	49		W	1	Cloudy.
	2 0	47	58	29,31	9	49		W	1	Cloudy.
24	8 0	33	52	29,37	1	33		W	1	Fine.
	2 0	49	58	29,33	11	53		W	1	Cloudy.
25	8 0	36	50	29,48	7	32		W	1	Cloudy.
	2 0	36	48	29,39	7	38		W	1	Cloudy.
26	8 0	27	46	29,40	3	28		W	1	Fine.
	2 0	36	47	29,51	18	39		W	1	Fine.
27	8 0	31	45	29,44	5	31		E	1	Fine.
	2 0	35	47	29,45	6	38		ESE	1	Fine.
28	8 0	35	45	29,47	9	31		E	1	Cloudy.
	2 0	33	50	29,48	4	34		E	1	Snow.
29	8 0	28	44	29,61	6	29		SE	1	Cloudy.
	2 0	32	46	29,63	3	34		W	1	Fine, rather hazy.
30	8 0	30	48	29,52	4	24		W	1	Cloudy.
	2 0	32	46	29,46	5	33		W	1	Cloudy.
31	8 0	30	43	29,34	3	29		W	1	Cloudy.
	2 0	38	47	29,35	11	41		W	1	Fine.

Rain this Month 1,873 Inches.

1819.	Thermometer without.			Thermometer within.			Barometer.*			Leslie's Hygrometer.			Six's Thermometer.			Rain,†
	Greatest height.	Least height.	Mean height.	Greatest height.	Least height.	Mean height.	Greatest height.	Least height.	Mean height.	Greatest height.	Least Height.	Mean height.	Greatest height.	Least height.	Mean height.	
	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Inches.	Inches.	Inches.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Inches.
January	52	32	41,8	60	41	51,8	30,49	29,22	29,78	28	2½	11,0	50	32	42,5	0,789
February	51	30	41,9	59	47	52,2	30,04	29,02	29,65	34	3	13,0	58	30	42,5	1,638
March	57	36	46,0	63	46	54,0	30,30	29,21	29,87	50	4	17,1	60	36	46,3	1,010
April	65	39	50,7	69	52	59,1	30,22	29,11	29,78	52	3	19,8	67	38½	51,5	1,694
May	68	48	57,3	65	52	59,7	30,21	29,10	29,73	56	4	21,6	71	40	57,5	1,400
June	70	51	59,7	70	56	61,8	30,28	29,58	29,90	39	3	16,9	72	46½	59,5	1,017
July	75	56	64,6	74	60	66,4	30,21	29,32	29,88	61	8	24,2	81	50½	64,9	0,750
August	75	55	67,0	76	63	68,2	30,31	29,20	29,99	73	5	27,1	80	52	67,2	0,250
September	71	50	60,7	72	56	63,3	30,45	29,47	29,94	56	2	23,4	73	47	60,7	1,320
October	70	34	51,5	70	46	57,3	30,31	29,23	29,79	60	0	14,7	70	32	58,9	1,069
November	56	29	42,9	64	46	52,9	30,08	29,11	29,71	25	0	8,6	60	21	42,7	0,917
December	55	18	38,4	60	42	52,2	30,17	29,24	29,71	17	0	6,0	54	18	38,9	1,873
Whole year			51,9			58,2			29,81			16,8			52,7	13,727

* The quicksilver in the bason of the barometer, is 81 feet above the level of low water spring tides at Somerset-house.

† The Society's Rain Gage is 114 feet above the same level, and 75 feet 6 inches above the surrounding ground.